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ASSOCIATION D'OCÉANOGRAPHIE PHYSIQUE

Union Géodésique et Géophysique Internationale

PROCÈS-VERBAUX Nº 3

GENERAL ASSEMBLY

at

WASHINGTON

September 1939

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Secrétariat de l'Association: The University, Liverpool 3

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The Association issues two series of publications, viz. "Publications Scientifiques" and "Procès-Verbaux."

The following numbers have already appeared:—

PUBLICATIONS SCIENTIFIQUES.

No. 1. S. F. GRACE:
I. Historical review of dynamical explanations of tides in non-elongated enclosed seas and lakes.
II. Historical review of dynamical explanations of the tides of the Mediterranean, the Baltic Sea, the Gulf of Mexico, and the Arctic Ocean. (1931.)

No. 2. Tidal Bibliography (Third instalment). (1932.)

No. 3. Bibliography on tides and certain kindred matters (Fourth instalment). (1936.)

No. 4. PHIL E. CHURCH: Temperatures of the Western North Atlantic from thermograph records. (1937.)

No. 5. Monthly and annual mean heights of sea-level, up to and including the year 1936. (1940.)

No. 6. Bibliography on tides and certain kindred matters (Fifth instalment). (1939.)

No. 7. J. P. JACOBSEN and MARTIN KNUDSEN: Urnormal 1937 or Primary Standard sea-water 1937. (1940.)

PROCÈS-VERBAUX.

No. 1. Cinquième Assemblée Générale réunie à Lisbonne Septembre 1933. (1934.)

No. 2. General Assembly at Edinburgh, September 1936. (1937.)

These publications form a continuation of the "Bulletins de la Section d'Océanographie de l'Union Géodésique et Géophysique Internationale," of which there were 17 numbers, No. 1 being issued in 1921 and No. 17 in 1931.

The General Assembly of the
Association was held on the occasion
of the Seventh General Assembly of the
Union. The meetings of the Association were held
in the rooms of the George Washington
University at Washington from the
7th to the 14th September 1939

Contents.

	PAGE
Officers and Members of Committees . . .	5
Delegates and Guests	10
Agenda	12
Reports of Meetings	20
Members of Committees as appointed at the Assembly	50
Presidential Address	52
General Resolutions	68
Administrative Reports	70
Reports of Committees	74
Abstracts of Communications	103

Officers and Executive Committee

President: Professor B. HELLAND-HANSEN, Det Geofysiske Institutt, Bergen.

General Secretary: Professor J. PROUDMAN, The University, Liverpool, 3.

Members of Executive Committee:

Admiral E. CABALLERO Y LASTRES.
Mr. D. J. MATTHEWS.
Professor T. G. THOMPSON.
Professor R. WITTING.
— To retire in 1939.

Professor M. KNUDSEN.
Dr. T. OKADA.
Dr. A. RAMALHO.
Mr. P. M. VAN RIEL.
— To retire in 1942.

Local Secretary for the Assembly:

Captain P. C. WHITNEY, Coast and Geodetic Survey.

Scientific Committees

Appointed by General Assembly at Edinburgh

Committee on Tides

Secretary: J. PROUDMAN.

Members: A. Courtier, A. Defant, J. E. Fjeldstad, J. G. F. Hooykaas, J. P. Jacobsen, H. A. Marmer, S. E. Stenij, H. U. Sverdrup, M. Tenani, H. Thorade, F. Vercelli.

Committee on Mean Sea-level and its Variations

Chairman :	R. WITTING.
Secretary :	J. PROUDMAN.
Members :	H. A. Marmer, J. D. Nares, J. Vignal.

Committee on Chemical Methods and Units

Chairman :	B. HELLAND-HANSEN.
Secretary :	J. P. JACOBSEN.
Member :	T. G. Thompson.

Committee on the Proposed International Survey of the Gulf Stream Area

Convener :	B. HELLAND-HANSEN.
Members :	D. Cot, A. Defant, J. A. Edgell, C. O'D. Iselin, M. Knudsen.

This Committee has power to co-opt additional members.

Committee on Criteria and Nomenclature for the Major Divisions of the Ocean-bottom

Chairman :	T. WAYLAND VAUGHAN.
Secretary :	President of International Hydrographic Bureau.
Members :	D. Cot, J. A. Edgell, B. Helland-Hansen, P. M. van Riel, G. Wüst.

Hydrographers of Japanese, Netherlands, Norwegian and United States Navies. Direktor der Nautischen Abteilung der Deutschen Marineleitung.

Joint Committee of Associations for Physical Oceanography and for Meteorology on Questions of Interaction between the Sea and the Atmosphere

Convener : H. U. Sverdrup.
Members : C. O'D. Iselin, H. Mosby, J. B. Tait, G. Wüst.

Committee on Gravity at Sea

(*To collaborate with the corresponding Committee of the Association for Geodesy*)

Convener : D. Cot.
Members : H. B. Bigelow, A. Defant, J. A. Edgell, N. H. Heck, B. Helland-Hansen, L. R. Leahy, A. B. McManus, J. Proudman, P. de Vanssay de Blavous.

Commission pour l'Étude des Raz de Marée

This is a joint commission of the Associations for Physical Oceanography, Meteorology, Seismology, Vulcanology.

President : A. Imamura, Imperial University, Tokyo.
Secretary : H. Hubert, 5 rue Raynouard, Paris, 16.

National Committees for Physical Oceanography

Belgium.

President : M. C. van Mierlo, Ingénieur, Avenue de la Reine 72, Ostende.

Canada.

President : Dr. W. Bell Dawson, 7 Grove Park, Westmouth.

DENMARK.

President : Professor Dr. M. Knudsen, Danmarks Tekniske Højskole, Sølvgade 83, København, K.

Secretary : Professor J. P. Jacobsen, Charlottenlund Slot.

FINLAND.

President : Professor R. Witting, Tölögatan, Helsingfors, 12.

Secretary : Dr. S. E. Stenij, Havsforskningsinstitutet, Helsingfors.

FRANCE.

Secretary : M. L. Pelissier, 13 rue de l'Université, Paris.

GREAT BRITAIN.

President : Rear-Admiral J. A. Edgell, Hydrographic Department, The Admiralty, London, S.W.1.

Secretary : Mr. D. J. Matthews, 10 Kew Gardens Road, Kew, Surrey.

GREECE.

President : The Minister of National Economy.

Vice-President : Captain A. Chryssanthis, Greek Navy.

Secretary : N. Sperantzas, Inspector of Fishery Department, Ministry of the Marine, Athens.

HOLLAND.

President : Professor E. van Everdingen, Koninklijk Nederlandsch Meteorologisch Instituut, De Bilt.

Secretary : Dr. C. Braak, Koninklijk Nederlandsch Meteorologisch Instituut, De Bilt.

JAPAN.

President : Dr. T. Okada, Central Meteorological Observatory, Tokyo.

Secretary : Mr. M. Y. Ishimaru, National Research Council, Imperial Academy House, Ueno Park, Tokyo.

MOROCCO.

President : Dr. J. Liouville, Institut Scientifique Chérifien, 2 rue de Foucauld, Casablanca.

Secretary : Capitaine de Corvette G. Roux, Institut Scientifique Chérifien, 2 rue de Foucauld, Casablanca.

NORWAY.

President and Secretary : Professor B. Helland-Hansen, Det Geofysiske Institutt, Bergen.

Secretary : Dr. H. Mosby, Det Geofysiske Institutt, Bergen.

PORTUGAL.

President : President, Comissão de Estudos de Oceanografia e Pesca, Ministério de Marinha, Lisbõa.

Secretary : Dr. A. Ramalho, Acquario Vasca da Gama, Dafùndo, Lisbõa.

UNITED STATES.

President : Dr. C. O'D. Iselin, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Secretary : Captain P. C. Whitney, Coast and Geodetic Survey, Washington, D.C.

International Members of the Association

CONSEIL PERMANENT INTERNATIONAL POUR L'EXPLORATION DE LA MER.

President : Professor J. Hjort, The University, Oslo, Norway.

Secretary : Captain W. Nellemose, Charlottenlund Slot, Denmark.

COMMISSION INTERNATIONALE POUR L'EXPLORATION SCIENTIFIQUE DE LA MER MÉDITERRANÉE.

President : S. E. le Grand Amiral Duc P. Thaon di Revel.

Secretary : Dr. E. le Danois, Office Scientifique des Pêches Maritimes, 3 Avenue Octave Gréard, Paris.

CONSEJO OCEANOGRÁFICO IBERO-AMERICANO.

President : Professor O. de Buen, Lagasca 116, Madrid.

Secretary : Professor R. de Buen, Alcala 31, Madrid.

INTERNATIONAL HYDROGRAPHIC BUREAU.

President : Vice-Admiral J. D. Nares, International Hydrographic Bureau, Monaco.

INTERNATIONAL COMMITTEE ON THE OCEANOGRAPHY OF THE PACIFIC.

Chairman : Professor T. G. Thompson, Oceanographic Laboratories, University of Washington, Seattle, U.S.A.

Delegates and Guests attending General Assembly

Canada.

H. B. Hachey.

Denmark.

D. la Cour.
J. Egedal
M. Knudsen.
Bruun de Neergaard

Great Britain.

L. H. N. Cooper.
J. Proudman.
J. D. H. Wiseman.

Japan.

K. Hidaka.

Mexico.

A. R. V. Arellano.

Netherlands.

L. Lek.

Norway.

Aagot Borge.
B. Helland-Hansen.
H. Mosby.

Poland.

H. Arctowski.
Wl. Gorczyński.

Sweden.

V. W. Ekman.

UNITED STATES.

K. T. Adams.
A. L. Barrows.
G. S. Bryan.
W. H. Bucher.
P. E. Church.
H. H. Clayton.
L. O. Colbert.
L. A. Cole.
G. D. Cowie.
L. P. Disney.
M. Ewing.
A. G. Fiedler.
R. H. Fleming.
C. K. Freen.
O. B. French.
Jewell J. Glass.
F. J. Haight.
A. F. Hassan.
M. King Hubbert.
C. O'D. Iselin.
W. L. G. Joerg.
W. C. Krumbein.
J. M. LeRoy.
H. A. Marmer.
G. F. McEwen.
R. B. Montgomery.
K. J. Murata
R. C. Murphy.
C. L. Newcombe.
R. A. Olson.
N. W. Rakestraw.
O. S. Reading.
R. R. Revelle.
T. B. Ried.
G. T. Rude.
R. J. Russell.
R. T. Sanders.
Sophia Saucerman.
P. Schureman.
H. R. Seiwell.
W. Shafnos.
E. H. Smith.
P. A. Smith.
F. M. Soule.
A. F. Spilhaus.
Taisia Stadnichenko.
H. C. Stetson.
H. U. Sverdrup.
T. G. Thompson.
C. L. Utterback.
T. Wayland Vaughan.
A. Vine.
W. G. Watt.
P. C. Whitney.
G. P. Woollard.

CONSEIL INTERNATIONAL POUR L'EXPLORATION DE LA MER.

J. P. Jacobsen.

General Assembly at Washington September 1939

Agenda

The items numbered by decimals were not circulated four months before the General Assembly.

A. President's Address

B. Administration

1. Report of the General Secretary for the period 1936–1939.
2. Financial report for the period 1936–1938.
3. Financial estimates for the period 1939–1941.
4. Election of the President, Vice-President, General Secretary and members of the Executive Committee.

4·1. Election of Association representative on Union Committee of administration and Finance.

5. Consideration of proposals submitted to the Union by the National Committees for Denmark, Germany and Great Britain.

C. Appointment of Scientific Committees

1. Committee on tides.
2. Committee on mean sea-level and its variations.
3. Committee on chemical methods and units.
4. Committee on the international survey of the Gulf Stream area.
5. Committee on criteria and nomenclature for the major divisions of the ocean bottom.
6. Committee on internal waves (proposed by Professor H. Pettersson, Sweden).
7. Committee on submarine daylight (proposed by Professor H. Pettersson, Sweden).

8. Joint Committee of Associations for Meteorology and for Physical Oceanography on questions of interaction between the sea and the atmosphere.
9. Joint Committee of Associations for Geodesy and for Physical Oceanography on gravity at sea.
10. (Jointly with other Associations) Committee on earth-tides.
11. (Jointly with other Associations) Commission pour l'étude des raz de marée.

D. Reports of Scientific Committees

1. Committee on tides.
2. Committee on mean sea-level and its variations.
3. Committee on chemical methods and units.
4. Committee on the international survey of the Gulf Stream area.
5. Committee on criteria and nomenclature for the major divisions of the ocean bottom.
6. Joint Committee of Associations for Meteorology and for Physical Oceanography on questions of interaction between the sea and the atmosphere.
7. Joint Committee of Associations for Geodesy and for Physical Oceanography on gravity at sea.
8. Joint Committee of Associations for Geodesy and for Physical Oceanography on earth-tides.
9. (Jointly with other Associations) Commission pour l'étude des raz de marée.

E. Reports from Recipients of Grants-in-aid.

1. M. Knudsen: The preparation of a new primary standard of sea-water.
2. J. W. Sandström: Researches on the interaction between the sea and the atmosphere.
3. A. Ångström: An experimental investigation of the possibilities of standardising photo-electric cells used in oceanography by means of solar radiation.
4. C. L. Utterback: A visit to the oceanographical institutes of Western Europe.

F. Proposals for Resolutions

1. G. Böhnecke:

   a. Die Internationale Vereinigung hält eine intensive internationale Erforschung der vertikalen und horizontalen Wasserbewegungen eines Randmeeres, z. B. der Nordsee, hervorgerufen durch Gezeiten, Wind und Luftdruck, für erforderlich.

   b. Die Internationale Vereinigung spricht den Wunsch aus, dass sämtliche Anliegerstaaten des ausgewählten Meeresgebietes die Aufzeichnungen ihrer Küstenpegel und ihre meteorologischen Beobachtungen für einen zu verabredenden Zeitbereich der Vereinigung zur Verfügung stellen.

2. A. Schumacher:

   a. Punkt XXVI der Beschlüsse und Wünsche der 6. Generalversammlung der Internationalen Vereinigung in Edinburg im September 1936, der die Erforschung der Dünung betrifft, wird auf die Erforschung des Seegangs im allgemeinen erweitert.

   b. Die Internationale Vereinigung spricht den Wunsch aus, dass auf den transozeanischen wie auf den Küstenrouten neben den üblichen Angaben über Seegang und Dünung von besonders geschulten Beobachtern (Schiffsoffiziere) möglichst sorgfältige Zahlenangaben über Höhe, Länge und Periode des Seegangs und der Dünung gesammelt werden.

   c. Um gleichzeitig die exakte Messung zu fördern, spricht die Internationale Vereinigung den Wunsch aus, dass von Forschungs- und Feuerschiffen aus der Seegang durch einheitliche selbstschreibende Messgeräte (nach Pabst) gemessen wird.

3. A. Defant:

   Die Internationale Gesellschaft für Physikalische Ozeanographie bewilligt eine finanzielle Beihilfe, damit die im Institut für Meereskunde (Deutsche Atlantische Expedition) bearbeitete Karte des Atlantischen Ozeans in 1 : 5 000 000 (Grundkarte

der ozeanischen Lotungen) weitergeführt werden und auch auf die anderen Ozeane ausgedehnt werden kann.

G. General Discussions

I. 1. W. Hansen: Neuzeitliche Geräte für Wasserstands- und Strommessungen.

2. British National Committee: Off-shore tide-gauges.
A. T. Doodson: Some experiments with the marégraphe plongeur Favé.

3. V. W. Ekman: Measurements of ocean currents on board the *Armauer Hansen* in 1930.

4. A. T. Doodson: A new electrically recording current-meter.

5. R. Revelle: Current measurements near the sea-bottom.

6. J. N. Carruthers: Instruments, methods and certain results, relating to a scheme of continuous current observing in the North Sea.

II. National Committees for Great Britain and Norway: Turbulence.

1. C. G. Rossby:

2. H. U. Sverdrup:

3. J. Proudman: An attempt to measure the frictional forces in a tideway.

4. G. F. McEwen: Some calculations of vertical velocity and turbulence in the North Pacific near Southern California.

III. National Committee for Norway: The interaction between the sea and the atmosphere.

1·1. K. Hidaka: Wind circulation of water and the inertia terms.

1·2. Resolution of the International Meteorological Committee.

IV. Section Nationale Française: Observation et enregistrement de la houle (amplitude, période, direction).

1·1. K. Hidaka: Studies on ocean waves by stereoscopic and cinematographic methods.

V. O. Pratje: Die Abbildungsmöglichkeiten der physikalischen und chemischen Eigenschaften des Ozeanwassers in den Sedimenten am Meeresboden.

Begründung: Da die Sedimente am Meeresboden in der Hauptsache von den im und auf dem Ozean wirksamen Faktoren abhängig sind, stellen sie gewissermassen eine Abbildung des langjährigen Mittels dieser Faktoren dar. Daher kann man umgekehrt aus den Sedimenten auf die Wassereigenschaften schliessen.

VI. A. Wechmann: Untersuchungen darüber, ob langjährige Änderungen der mittleren Wasserstände (Tidehochwasser, Tideniedrigwasser, Tidemittelwasser) an den Küsten des Atlantischen und des Pazifischen Ozeans festzustellen sind und wie sie erklärt werden können.

VII. H. Wattenberg: Prüfung, inwieweit eine Vereinheitlichung der heute gebräuchlichen Untersuchungsmethoden und Bezeichnungen für die im Seewasser einerseits und im Süsswasser andererseits vorkommenden gemeinsamen Bestandteile möglich ist, um einen Vergleich der in beiden Bereichen gewonnenen Ergebnisse sicherzustellen.

Eine Gegenüberstellung der in beiden Bereichen üblichen Verfahren und Nomenklaturen wird zu der Generalversammlung oder schon vorher geliefert werden.

H. Reports and Lectures

1. International Hydrographic Bureau: Report on the work carried out by the Bureau.
2. International Committee on the Oceanography of the Pacific: Report on oceanographical activities in the Pacific.
3. Section d'Océanographie Physique du Comité National Français: Rapport sur les travaux d'océanographie physique exécutés en France et dans les colonies françaises en 1936 à 1939.

3·1. United States Hydrographic Office: Oceanographic activities.

3·2. United States Coast and Geodetic Survey: Oceanographic activities.

4. P. M. van Riel: Reports on work carried out by Netherlands institutions.

5. A. Defant: Deutschlands Anteil an der internationalen Golfstrom-Untersuchung im Mai und Juni 1938.

6. A. Defant: Über die ozeanographischen Arbeiten der Deutschen Nordatlantischen Expedition auf ihren zwei Teilfahrten Februar bis Mai 1937 und Januar bis Juli 1938.

7. C. O'D. Iselin: A study of the variations in strength of the Gulf Stream, 1937–1939.

7·1. H. B. Hachey: The probable significance of temporary migrations of Gulf Stream water on the Atlantic Seaboard.

8. J. B. Tait: Fluctuations in the North Atlantic drift current through the Faeroe-Shetland Channel.

8·1. H. R. Seiwell: Internal waves in the Atlantic.

9. J. Goodman, T. G. Thompson and F. A. Zeusler: Observations on the waters of the Arctic Ocean off the Alaskan coast.

10. T. G. Thompson, F. A. Zeusler, J. Goodman and others: Summary of observations in Bering Sea and Bering Strait in 1937 and 1938.

11. R. Revelle: Vertical circulation in the Central North Pacific.

12. R. H. Fleming: Equatorial water masses of the Pacific.

13. R. H. Fleming: The California Current in 1937, 1938 and 1939.

14. H. U. Sverdrup: The Gulf of California.

15. G. Wüst: *a*. Die Grenzen der Ozeane und Meere.
b. Ein Vorschlag über eine internationale Verständigung auf diesem Gebiete.

16. G. Wüst: Zur Nomenklatur der Grossformen der Ozeanböden.

16·1. W. L. G. Joerg: The representation of bathymetry on the international map of the world.

17. A. Defant: Das physikalische Meeresniveau des Atlantischen Ozeans.
17·1. K. Hidaka: Horizontal oscillations of bay water induced by tidal currents.
18. E. C. LaFond: Sea-level and surface temperatures along the coast of California.
19. Th. Hesselberg: Secular variation of the surface temperature of the sea along the Norwegian coast.
20. H. U. Sverdrup: Do deep-sea currents exist?
21. F. M. Soule: Consideration of the depth of the motionless surface near the Grand Banks of Newfoundland.
22. E. G. Moberg: The distribution of phosphate in the sea as an index of water movements.
22·1. H. R. Seiwell: The maxima and minima of sea-water properties in relation to oceanic circulation.
23. T. G. Thompson and J. Goodman: Characteristics of the waters, Hawaii to Cape Flattery and Cape Flattery to Aleutian Islands.
24. R. J. Robinson and T. G. Thompson: Tidal cycle variations in the composition of sea-water.
25. H. Mosby: An oceanographic thermo-sounder.
26. A. F. Spilhaus: Rapid-measuring hydrographic instruments and the determination of quasi-synchronous conditions in impermanent current systems.
27. C. L. Utterback: The spectral distribution and total energy of daylight in the waters of the Pacific North West.

28. G. F. McEwen: Vertical and off-shore dispersion of silt from the Southern California shore.
29. C. L. Utterback: The radium content of ocean bottom samples in the Pacific, Bering Sea and the Arctic.
30. J. D. H. Wiseman: The organic content of marine sediments from the Arabian Sea.

Absence of Delegates

On account of the absence of certain delegates the items *B* 3, 4, *C* 9, *D* 7, *F* 1, 2, 3, *G* I 1, 6, V, VI, VII, *H* 1, 4, 5, 6, 8, 15, 16, 17 were not considered.

The items *H* 22, 22·1 were withdrawn.

Invitation to visit Woods Hole Oceanographic Institution

The Director of this Institution extended a cordial invitation to all delegates and guests attending the General Assembly of the Association of Physical Oceanography, to visit the Laboratory of the Institution at Woods Hole, Massachusetts.

Reports of Meetings

First General Meeting of the Association

Thursday, 7th September 1939

The Meeting opened at 10.00, when the Chair was taken by the President, Professor Helland-Hansen. Thirty-five delegates and guests were present.

The PRESIDENT opened the General Assembly as follows:

"First of all I wish to give you a most hearty greeting of welcome to this General Assembly of our Association. The events that stir the whole world have their serious effects also upon our meeting here. We miss many representatives who otherwise would have come. In fact many of them were already under way, but had to break their journey and return home, filled with troubled thoughts as to the future of their countries and of their homes, and I think also of their relations to colleagues from elsewhere. We may all of us be concerned in the fateful international conflicts, but when coming together as we now do, we feel the ties which in a friendly way combine us in mutual interests and willingness to further objective and ideal activities in science.

"This Assembly will not proceed along quite the same lines as usual. According to decisions agreed upon, the General Assembly of the Union will not now consider administrative and financial matters, and will have no elections carried out. It is also assumed that the individual Associations on this occasion will restrict themselves to scientific matters and postpone elections and other items to a later date. This decision is dictated by the loyal point of view that as delegates from so many countries have been prevented from being present here,

it would be unfair to carry out elections and various administrative matters now. On the other hand, our American hosts and many of the delegates who are here have made so many valuable preparations with regard to scientific matters that we must use the opportunity of having the benefit of their work. I feel confident that we shall have a comprehensive meeting and obtain many impulses of lasting value from lectures, discussions and personal relations. In this feeling we shall now start our deliberations.

"Before starting, however, we will remember two active collaborators in our Association who have died since our last Assembly.

"I am very sorry to have to report the death of Monsieur E. Fichot, our Vice-President and Chairman of our Committee on Tides. He was 'Membre de l'Institut et du Bureau des Longitudes, Ingénieur hydrographe général de la Marine.' Besides his work as hydrographic engineer, he wrote much on the dynamical theory of tides, being a mathematician of distinction. He died on 18th July 1939. (See p. 136.)

"I have also to report the death, on 1st November 1936, of Dr. S. Ogura, a very valuable member of our Committee on Tides and also a member of the Ocean-Bottom Committee. He was Superintendent of Tidal Work in the Hydrographic Department of the Japanese Navy."

(All those present rose in tribute to the memory of Monsieur Fichot and Dr. Ogura.)

It was agreed that Professor T. G. Thompson should be appointed Acting Vice-President for the Washington Assembly.

H 3·1. Captain Bryan read a paper on the "Oceanographic Activities of the United States Hydrographic Office." (See p. 145.)

The President and Dr. Wayland Vaughan spoke in appreciation of the oceanographic work done by the U.S. Hydrographic Office.

H 3·2. Admiral Colbert read a paper on the "Oceanographic Activities of the United States Coast and Geodetic Survey." (See p. 149.)

The PRESIDENT, Dr. SVERDRUP and Dr. ISELIN made appreciative remarks.

Lieut. P. A. SMITH said: "In the collection and publication of the vast quantity of echo-soundings throughout the oceans of the world, we have a task that will tax the resources of the national hydrographic offices. But there is one thought that deserves mention. Modern echo-sounding equipment makes it possible to obtain accurate soundings from any commercial or naval vessel, but, due to the natural limitations in position-finding methods in ordinary navigation, the use of a number of echo-sounding profiles in arriving at a reasonable relative adjustment in position of lines is a point that must be borne in mind. The forms on the sea-floor are reasonable land shapes, contrary to some past theories, and the use of physiographic knowledge and experience in the analysis of the sounding lines is necessary in obtaining the best oceanic charts from the available and rapidly accumulating data. From the broad viewpoint we have then two major problems: (1) asembling the small-scale charts covering oceanic areas and outlining the major features; (2) surveying and compiling large-scale maps of local areas, which from the general charts may be believed to have important commercial or scientific significance. That such oceanic features may have commercial significance other than their use in position-finding from echo-soundings is apparent with the development of devices already an actuality in at least one case for recovering ocean bottom sediments in commercial quantities and at costs that are economically feasible.

"Any action this Union can take in formulating systematic and standardised methods for accumulating and publishing the ever-growing mass of sounding data from oceanic areas will be welcomed, I am sure, by the hydrographic engineers of the world."

H 3. The GENERAL SECRETARY submitted a "Rapport d'ensemble sur les traveaux d'Océanographie physique effectués en France de Septembre 1936 à Septembre 1939," which he had received from Monsieur Pélissier. (See p. 135.)

H 2. Professor T. G. THOMPSON made a report on the work of the International Committee on the Oceanography of the Pacific.

E 1. Professor KNUDSEN presented the report "Urnormal 1937 or Primary standard sea-water 1937." This is to be published by the Association as *Publication Scientifique* No. 7.

The PRESIDENT said: "We have to express our gratitude to Professor Knudsen for the very important task which he has carried through, making it possible to obtain perfectly comparable salinity determinations from the beginning of this century far into the future."

Professor EKMAN said: "As Professor Knudsen has mentioned, I was charged, thirty-six years ago, with the task of preparing a primary standard water in the International Central Laboratory at Kristiania (now Oslo). Perhaps therefore I may be allowed to express here the deep satisfaction which I have long felt, and which I feel still more strongly after having heard the present communication, that the preparation of standard water was, after the definitive closing of the Central Laboratory, once more entrusted to Professor Knudsen's well-known mastership."

D 3. Professor JACOBSEN submitted the Report of the Committee on chemical methods and units. (See p. 75.) This report and its recommendations were unanimously adopted.

Professor JACOBSEN then described the questions which had still to be settled. The Committee proposed to introduce the terms "torr" in connection with standard pressure, "val" for equivalent, and "cline" in connection with the halogen-content of sea-water.

Dr. COOPER said: "Although the attainment of greater precision in the statement of the results of experiment may demand the coinage of new expressions, every effort should be made to keep such new coinages to a minimum. Otherwise our literature becomes so cluttered with jargon as to become unintelligible to any but specialists. Moreover, such terms are the better if reasonably self-explanatory. Is there real need for such terms as 'torr,' 'val' and 'cline' in oceanography?"

He insisted on the importance of all authors stating very explicitly, in a recognised scientific language, all details of

analysis, including correction terms and factors. He instanced the great mass of chemical data which has appeared in Japanese publications. Although it is quite understandable that the Japanese choose to publish in their own language and script, the absence of such an explicit statement in a Western language means that all this work, no doubt of much value, will undoubtedly be lost to others.

Professor JACOBSEN remarked that the units "val" and "torr" had been adopted in several countries. Some remarks had been made on the definitions of several of the concentrations of constituents of sea-water. In the case of phosphate it was emphasised by the Committee that the method of determination should be stated and that attention should be paid to the concentration of arsenate.

Dr. REVELLE stated that he agreed with Dr. Cooper's objections to the introduction of new words for old concepts in chemical oceanography. In particular he suggested that "cline" was no more necessary in 1939 than it had been in 1900, since "chlorinity" has never referred to the actual concentration of chloride but to that of a fictive substance, viz. all the halides reckoned as chloride. The definition of chlorinity must be given or implied in any case, and it would seem to be an unnecessary complication to introduce an invented word which must in turn be defined.

Dr. FLEMING said: "'Cline' is really an abbreviation for the expression 'chlorinity' referred to the original standards established by Knudsen and Sørensen on the basis of the atomic weights of 1900."

The PRESIDENT said: "It has been our intention to publish a standard work on definitions, units and methods to be used in chemical oceanography. The methods will be described in all detail. When following these methods, an author need not publish particulars as to his analytical procedures, but need only refer to the standard work published by the Association. The terms 'cline,' 'val' and 'torr' will receive further consideration."

It was agreed that the discussion should be adjourned until the afternoon of 8th September 1939.

E 2, 3, 4. The GENERAL SECRETARY stated that the reports submitted by Dr. Sandström, Dr. Ångström and Professor Utterback had been examined by the Executive Committee of the Association.

B 1. The GENERAL SECRETARY submitted his Report for the period 1936–1939. (See p. 70.) This was adopted unanimously.

B 2. The GENERAL SECRETARY submitted the Financial Report for the period 1936–1938. (See p. 70.) Drs. T. Wayland Vaughan and C. O'D. Iselin were appointed Auditors of this report. (See p. 73.)

B 5. It was agreed that the General Secretary of the Association should be appointed to represent the Association on the Committee of the Union which was to examine the Danish proposal relating to the "Service des Échanges Internationaux."

Second General Meeting of the Association

Thursday, 7th September 1939

The Meeting opened at 14.30, when the Chair was taken by the President, Professor Helland-Hansen. Thirty-two delegates and guests were present.

H 9, 10. Professor THOMPSON read the two papers by himself, J. Goodman and F. A. Zeusler on "Observations on the waters of the Arctic Ocean off the Alaskan coast" (see p. 160), and "Summary of observations in Bering Sea and Bering Strait in 1937 and 1938" (see p. 162).

There followed a short discussion in which the PRESIDENT and Dr. WAYLAND VAUGHAN took part.

H 11. Dr. REVELLE read his paper on "Vertical circulation in the Central North Pacific." (See p. 164.)

Professor MCEWEN said: "Vertical circulation is of more importance than might at first sight be inferred from its very small velocity as compared with that of horizontal currents. The compensating effects of the relatively large cross-sections of such vertical currents and the relatively large vertical gradients of water-properties should be considered."

H 12, 13. Dr. FLEMING read his papers on "Equatorial water masses of the Pacific" (see p. 166), and "The California Current in 1937, 1938 and 1939" (see p. 168).

H 14. Dr. SVERDRUP read his paper on "The Gulf of California." (See p. 170.)

Dr. MURPHY said: "Dr. Sverdrup's remarks on the upwelling and the periodical destruction of marine life on the continental side of the Gulf of California depict a mirror-image of what occurs on a much greater scale along the coast of Peru. His suggestion that the death of organisms in shallow water is due to vertical incidence of oxygen-deficient water has not been advanced to explain the Peruvian phenomenon of '*aguaje*' or

'Callao Painter.' In this periodical condition organisms of many classes die along a hundred or more miles of the coast, and there is a marked production of hydrogen sulfide in the littoral water."

The PRESIDENT said: "With reference to the remarks of Dr. Sverdrup about the differences in the distribution of bottom animals in the Gulf of California, it may be of interest to examine whether there is a connection between the zoogeographic findings and the occurrence of nodes and loops of standing waves."

Professor EKMAN asked if Dr. Sverdrup had had any opportunity of observing such slopes of isodense surfaces *across* the Gulf as ought to accompany the internal waves of long period which he had mentioned. Also, considering the relatively good simultaneity of the several cross-sections, might not such observed slopes give additional knowledge of the waves in question?

Dr. SVERDRUP answered: "Every cross-section shows transverse slopes of the isobaric surfaces. However, because the observations were not simultaneous, we have not attempted to interpret these slopes."

Professor KNUDSEN enquired about the correspondence between the oxygen-minimum at the entrance to the Gulf and that in the ocean outside the Gulf.

Dr. SVERDRUP said: "Observations on the 'Bushnill' at five stations across the wide entrance to the Gulf showed the same lack of oxygen at depths between 150 and about 1000 metres as did our observations in the Gulf of California."

Dr. WAYLAND VAUGHAN congratulated Dr. Sverdrup and his associates on their important contributions to the knowledge of the oceanography of the Eastern Pacific during the past three years.

H 23, 24. Professor THOMPSON read the papers by himself and J. Goodman on "Characteristics of the waters, Hawaii to Cape Flattery and Cape Flattery to Aleutian Islands" (see p. 186); and by himself and R. J. Robinson on "Tidal cycle variations in the composition of sea-water" (see p. 189).

Third General Meeting of the Association

Friday, 8th September 1939

The Meeting opened at 10.00, when the Chair was taken by the Acting Vice-President, Professor Thompson. Thirty-two delegates and guests were present.

Professor KNUDSEN was appointed to represent the Association on the Committee of the Union which was to examine and report upon the Report of the General Secretary of the Union.

The GENERAL SECRETARY of the Association was appointed to represent the Association on the Committee of the Union which was to examine and report upon the question of Repositories of geophysical information.

D 1. Professor PROUDMAN submitted the Report of the Committee on tides. (See p. 74.) This report was adopted unanimously.

C 1. It was agreed that the Committee should be reappointed with the addition of Dr. K. Hidaka and with Dr. H. A. Marmer as Chairman. (See p. 50.)

H 8·1. Dr. SEIWELL read his paper on "Internal waves in the Atlantic."

Dr. MARMER said: "Will Dr. Seiwell please tell us the relative magnitudes of the 24-hour wave and the 12-hour wave?"

Dr. SEIWELL answered: "The 24-hour amplitudes at this station were generally in excess of the 12-hour amplitudes."

Dr. SVERDRUP said: "Did I understand correctly that during thirteen days the isotherms below 17° rose continuously whereas the 19° isotherm sank?"

Dr. SEIWELL answered: "Yes."

Dr. SVERDRUP then said: "That appears to indicate that internal waves of much longer period must exist."

Dr. SEIWELL replied: "Yes, there appears always to be a divergence in long-period trend between the 17° and 18°

isotherms in the Western Sargasso Sea where there occurs the least stratified water."

C 6. It was then decided that the present time was not opportune for the appointment of a Committee on internal waves.

H 19. Dr. MOSBY read the paper by Th. Hesselberg on "Secular variation of the surface temperature of the sea along the Norwegian coast." (See p. 179.)

Professor UTTERBACK said: "I would like to ask Dr. Mosby if, in the last few years, there has been any measurement of solar energy absorbed by the sea, along the Norwegian or Icelandic coasts."

Dr. MOSBY answered: "Not as far as I know."

Dr. MARMER said: "Dr. Mosby's paper is of great interest to those of us who are dealing with the problem of sea-level. In general there has been a rise of sea-level for the past twenty-five years on the coasts of the United States."

Professor PROUDMAN said: "There has also been a rise of sea-level on the coasts of the North Sea."

The PRESIDENT mentioned a few details from studies of long-range variations in air-temperature and in the physical properties of the Atlantic water appearing in the deep parts of the Norwegian fjords. He emphasised the desirability of having co-ordinated, with regard to long-period variations, such elements as air-pressure (circulation), air-temperature, water-temperature and mean sea-level.

H 20. Dr. SVERDRUP read his paper on "Do deep-sea currents exist?" (See p. 182.)

Dr. SEIWELL said: "Is it possible that Antarctic water may be carried farther into the North Atlantic than has been proposed by Wüst's circulation scheme?"

Dr. SVERDRUP answered: "This analysis does not affect Wüst's results concerning conditions in the Central and North Atlantic, but presents a new interpretation of conditions in the Antarctic South Atlantic."

H 21. Mr. SOULE read his paper on "Consideration of the depth of the motionless surface near the Grand Banks of Newfoundland." (See p. 184.)

Commander E. H. Smith said: "In testing the reliability of dynamic topographic maps, this represents a worth-while contribution to our knowledge. The U.S. Coast Guard, in its administration of the Ice Patrol, has found a practical application of Bjerknes' formula in hydrodynamics. If this work can be improved, giving more accurate information on the behaviour of icebergs, the Coast Guard welcomes it. In general a close association and co-ordination between oceanographers and oceanographic institutions and the Coast Guard is recommended."

Fourth General Meeting of the Association

Friday, 8th September 1939

The Meeting opened at 14.30, when the Chair was taken by the President, Professor Helland-Hansen. Twenty-nine delegates and guests were present.

D 3. Professor THOMPSON re-opened the discussion on the Report of the Committee on chemical methods and units, and suggested the use of "cloron" instead of "cline."

Dr. FLEMING said: "'Chlorinity' would continue to have its present usage in physical oceanography, *i.e.* to compute σ_t, etc. It is only in certain problems in chemistry that any confusion may arise. Apparently it is to avoid this difficulty that the Committee has proposed the introduction of the terms 'cline' or 'cloron.'"

Professor KNUDSEN said: "It must be clear that the word 'cline' is a new expression for an old concept, and that it might perhaps have been introduced some twenty years ago, when the atomic weights had already been appreciably altered."

Dr. WAYLAND VAUGHAN moved the adoption of the word "chlorinity" as defined by Professor Knudsen in his "Urnormal 1937." This was agreed upon unanimously.

Dr. WAYLAND VAUGHAN also moved that the Committee on chemical methods and units should be continued, and that it should be given authority to seek advice from other competent experts. This was adopted unanimously.

It was then agreed that a meeting of the Committee should be held on 9th September, and that all those interested should be invited to attend.

G I 2, 4. Professor PROUDMAN read the papers by Dr. A. T. Doodson on "Some experiments with the marégraphe plongeur Favé" (see p. 110), and on "A new electrically recording current-meter" (see p. 113).

Professor EKMAN asked: "What is the diameter of the cable by which the current-meter is suspended?"

Mr. DISNEY asked: "Is it necessary to attach weights for strong currents? How long can a continuous record be obtained with the meter?"

Professor PROUDMAN answered: "The diameter of the cable is 1·3 cm. No weights are necessary for currents up to three knots. The meter can be operated for several days continuously."

G I 5. Dr. REVELLE read his paper on "Current measurements near the sea-bottom." (See p. 114.)

Professor PROUDMAN asked if Dr. Revelle was satisfied with a formula which involved $(z+z_0)/z_0$ when this is large and z_0 is not a precise physical constant.

Dr. REVELLE replied that he did not feel qualified to express an opinion about the theoretical merits of the logarithmic equation for velocity-distribution, but that it seemed to have the practical merit of describing the observed velocity profiles in a simple fashion.

Professor PROUDMAN said: "My question is intended to raise a point of practical utility. The logarithmic form appears to be very suitable, but the way in which the small uncertain z_0 enters into its argument seems to restrict its utility."

Dr. SVERDRUP said: "The formula has been used extensively in meteorological work. It has there been possible to relate the value of z_0 to the character of the surface. The wind-profile gives a small value of z_0 over a smooth surface, say a smooth lawn, but a large value of z_0 over a rough surface, say a wheat field."

Professor SPILHAUS said: "Dr. Revelle has shown roughness (z_0) up to 8 cm.; if the empirical factor suggested by Prandtl for the relationship between z_0 and the actual height of the roughness elements obtains here, this value of z_0 would imply roughness elements nearly $2\frac{1}{2}$ metres in height, and this is greater than the heights at which the several measurements were made. It is difficult to picture the meaning of such measurements under such conditions, and it can only be that the factor 30 in

$$\text{height of roughness elements} = 30z_0$$

is far too large."

Fifth General Meeting of the Association

Monday, 11th September 1939

The Meeting opened at 10.00, when the Chair was taken by the President, Professor Helland-Hansen. Forty-seven delegates and guests were present.

A. As this was the time arranged by the Union, Professor Helland-Hansen delivered his Presidential Address. (See p. 52.)

The President of the Union, Dr. La Cour, said: "On behalf of the audience I beg permission to thank you, Professor Helland-Hansen, for your most interesting address on a very important subject. Many members of other Associations would have listened with great pleasure, but all Associations are hard at work on their own matters. I am sure, however, that many will read your Address later and feel gratitude for the information which you have given. I know, also, that I am interpreting the wishes of numerous colleagues belonging to other branches of the Union when I express, in addition to our thanks for your Address, our hearty thanks and admiration for your personal contributions, both practical and theoretical, to the elucidation of the very important problems which you have discussed to-day."

D 4. Professor Helland-Hansen submitted the Report of the Committee on the proposed international survey of the Gulf Stream area. (See p. 79.)

Dr. Sverdrup said: "The work reported has clearly demonstrated the existence of complicated patterns of distributions of properties and currents. It appears to me that the time-variations of these patterns should now receive great attention. The same sections should therefore be repeated not 'twice at least' as recommended, but from four to six times. A series of 'synoptic charts' should be aimed at."

Professor KNUDSEN drew attention to the advantage of having two ships running the same section and taking the same stations at a few hours' interval.

The Report of the Committee was adopted unanimously.

C 4. The Committee on the proposed international survey of the Gulf Stream area was reappointed with the addition of H. A. Marmer and T. Wayland Vaughan, and with power to co-opt additional members. (See p. 50.)

The GENERAL SECRETARY read a letter from Dr. J. B. Tait expressing his deep regret and disappointment that circumstances had prevented his attendance at the Assembly.

G I 3. Professor EKMAN made his communication on "Measurements of ocean currents on board the *Armauer Hansen* in 1930." (See p. 111.)

H 7. Dr. ISELIN read his paper on "A study of the variations in the strength of the Gulf Stream, 1937–1939." (See p. 154.)

Sixth General Meeting of the Association

Monday, 11th September 1939

The Meeting opened at 14.30, when the Chair was taken by the President, Professor Helland-Hansen. Thirty delegates and guests were present.

D 3. Professor Helland-Hansen submitted the Report of the meeting of the Committee on chemical methods and units, which had been held on 9th September 1939. (See p. 78.) This report and its recommendations were adopted unanimously.

H 7·1. Mr. Hachey read his paper on "The probable significance of temporary migrations of Gulf Stream water on the Atlantic Seaboard." (See p. 156.)

The President said: "It seems likely that the lateral oscillations of the Gulf Stream, at the surface off the American coast, are the result of variations in the obliquity of the water-layers induced by variations in the velocity of the current. If the depth of the current and the difference of dynamic depth between the outer and inner limits of the current, referred to the under boundary, remain constant, the volume-transport of water will be the same. Does a definite correlation exist between velocity and volume-transport, or is a weakening of the current, for instance, connected with a rise of the under boundary?"

Dr. Iselin said: "The north-south variations of the axis of the Gulf Stream seem to be associated with changes in transport rather than with changes in velocity. It may be that a large transport is also associated with high velocities, but this correlation has not yet been demonstrated. For the present, therefore, only the transport changes can be stressed. The transport changes cause expansions and contractions of the

main North Atlantic eddy and thus influence the path of the Gulf Stream. Velocity variations would have similar consequences, but might be expected to be less pronounced and to have shorter periods."

G IV 1·1. *H* 17·1. Dr. HIDAKA read his papers on "Studies on ocean waves by stereoscopic and cinematographic methods" (see p. 125), and on "Horizontal oscillations of bay water induced by tidal currents" (see p. 174).

Professor PROUDMAN congratulated Dr. Hidaka on the large number of problems which he had solved during the last ten years or so.

H 26. Professor SPILHAUS read his paper on "Rapid-measuring hydrographic instruments." (See p. 192.)

H 25. Dr. MOSBY read his paper on "An oceanographic thermo-sounder." (See p. 190.)

Seventh General Meeting of the Association

Tuesday, 12th September 1939

The Meeting opened at 10.00, when the Chair was taken by the Acting Vice-President, Professor Thompson. Thirty-eight delegates and guests were present.

D 5. Dr. Wayland Vaughan submitted the Report of the Committee on criteria and nomenclature for the major divisions of the ocean bottom. This report will be published as *Publication Scientifique No.* 8.

The President expressed the appreciation of the Association for the very valuable work which Dr. Vaughan and the other members of the Committee had carried out.

The report was adopted unanimously.

C 5. The Committee was reappointed with the addition of W. L. G. Joerg and S. Kishindo. (See p. 51.)

H 16·1. Mr. Joerg read his paper on "The representation of bathymetry on the international map of the world."

Lieut. P. A. Smith said: "If this be not too controversial a subject, I should like to add a few thoughts by one who has struggled with the matter of delineation of oceanic topography on maps and charts.

"We have seen from Mr. Joerg's paper that there are two large problems of mapping the sea-floor. (1) Maps of continental or oceanic regions for general and limited scientific needs. These embrace largely areas in which the data are of a qualitative or incomplete nature. (2) The detailed and large-scale maps or charts of areas having a special navigational or geologic significance.

"There seems to have been a tendency when one leaves the shore to overlook the possibilities of contours. With proper scale and contour interval a solid shape can be shown at least

with equal contrast as regards its prominent features as can be done by use of graded tints.

"The use of brown contours and blue stream-lines or thalwegs has shown, from their employment on the excellent maps of the United States Geological Survey, that a readability as well as usability is obtained not approached by other forms. The conventional blue isobaths or contours as used on the continental slope charts, scale 1 : 120,000, fits in well with the additional requirements of charts. All of the submarine features about which we now have only fragmentary knowledge will eventually become of great value to the navigator and scientist in determining position from echo-soundings. In order to use the submarine topography for position it is essential to have a surface of paper upon which pencil lines are easily read and upon which notations are quite legible. The blue contours are especially adaptable to this use.

"Solid tints increasing in intensity with depth are expensive to print. Blue contours, by proper choice of interval and horizontal scale, can give a better presentation of the surface and can be omitted or obviously generalized when soundings are shown as in large areas with few soundings.

"Navigational needs, especially from the commercial standpoint and also from scientific considerations as regards position findings of vessels taking bottom samples or making other geophysical investigations, require a chart upon which position may be found quickly and easily from economic soundings. An approach to such a chart is found in Coast and Geodetic Survey Chart No. 5101 A of the south-western coast of California issued in 1938. Eventually we may hope to have charts for this purpose over much of the waters of the world. Until then we must satisfy the two needs pointed out by Mr. Joerg and mentioned in the first part of this comment."

In reply to Lieut. Smith's comment, Mr. Joerg said that he was glad of the opportunity to call attention to the fact that Lieut. Smith himself had contoured two of the five sheets in 1 : 120,000 of the series showing the Atlantic continental shelf and slope of North America that were on display.

As to the relative merits of contours and layer tints Mr. Joerg stated that this touches upon one of the basic problems

in the representation of relief on maps in general. With regard to the specific question raised by Lieut. Smith, Mr. JOERG was of the opinion that the validity of each method is to a large degree conditioned by scale. On the whole the layer method (with or without supporting contours) is desirable in the case of smaller-scale generalized maps, such as general bathymetric maps of the oceans, whereas contours alone, with appropriate close interval, are suitable for large-scale maps, such as topographic sheets or, in the field of navigation, coast charts, such as that of the off-shore area in south-western California mentioned by Lieut. Smith. The International Map of the World, although on a relatively large scale, is a summarizing map and is therefore more closely related to the generalized bathymetric maps of the oceans. The use of layer tints would therefore, it appears, heighten its synoptical quality.

As to the point of cost of printing layer tints as compared with contours only, there is no question that it is less expensive to print contours than layer tints. Within the layer system, however, it may be pointed out that the 17 bathymetric and 6 hypsometric tints on Stocks's experimental sheet South 0–26 do not call for more colour plates than the regular sheets of the International Map of the World, actually only four, namely yellow, blue, red and black.

H 28. Professor MCEWEN read his paper on "Vertical and off-shore dispersion of silt from the Southern California shore." (See p. 195.)

Dr. REVELLE said: "The application by Professor McEwen of the modern ideas of lateral mixing to the problems of transportation of suspended debris in the upper water-layers gives promise of a far-reaching application. Two avenues of investigation immediately suggest themselves: first, the possibility that the relative rate of accumulation of the red clay of the North Pacific may eventually be evaluated; second, that the greater understanding of the nature of the sedimentation in the basins of the California coast may be obtained. These basins are probably nearly strictly analogous as environments of sedimentation to the filled basins of the California coast ranges, some of which contain literally tens of thousands of feet of late Tertiary marine sediments."

H 29. Professor UTTERBACK read his paper on "Radium content of ocean bottom samples in the Pacific, Bering Sea and the Arctic." (See p. 197.)

Dr. WISEMAN congratulated Professor Utterback for the most interesting radioactive results obtained on shallow-water sediments. He was very interested to hear that Professor Utterback intended investigating the radioactivity of deep-sea oceanic sediments, collected by the Piggot sampler.

With regard to the method of expressing the amount of radium in sediments Dr. WISEMAN suggested that radium should be expressed on a H_2O – (loss at 105° C.) free basis, and in addition the amount of $CaCO_3$, NaCl and organic matter should be determined. By adopting this method the speaker felt sure that the results would be far more valuable to those attempting to interpret the variations in radioactive content of oceanic sediments.

Professor UTTERBACK replied: "The chemical constituents and physical properties are now being studied. The samples are preheated to drive off absorbed water. They are sampled and then heated to 1000° C. to drive off water of crystallization, carbonates and organic materials. They are then sealed for one month in order to permit equilibrium between radium and radon."

H 30. Dr. WISEMAN read the paper by himself and H. Bennett on "The distribution of organic carbon and nitrogen in sediments from the Arabian Sea." (See p. 199.)

D 9. It was announced that a meeting of the "Commission pour l'étude des raz de Marée" would be held on 14th September.

It was agreed that the Association should transmit to the Commission during the period before the next General Assembly the same proportion of the total income of the Association during that period as it had transmitted during the period since the Assembly at Edinburgh.

A Joint Meeting of the Associations of Geodesy, Meteorology, Physical Oceanography and Hydrology

Eighth General Meeting of the Association of Physical Oceanography

Tuesday, 12th September 1939

The Meeting opened at 14.45, when the Chair was taken by the President of the Union, Dr. D. la Cour.

There were present:

O. S. Adams.
P. I. Aguerrevere.
A. R. V. Arellano.
C. F. Baeschlin.
H. C. Barksdale.
L. V. Berkner.
W. Bowie.
M. L. Brashears.
H. B. Brown.
D. J. Cedarstrom.
L. A. Cole.
E. B. Collins.
L. H. N. Cooper.
D. la Cour.
F. L. Culley.
W. Darling.
J. A. Duerksen.
J. Egedal.
V. W. Ekman.
M. Ewing.
R. M. Field.
U. C. Fishel.
R. H. Fleming.
W. Gorczynski.
B. Gutenberg.
G. M. Hall.
B. Helland-Hansen.
J. B. Hersey.
K. Hidaka.
C. R. Horne.
A. J. Hoskinson.
M. K. Hubbert.
C. O'D. Iselin.
H. S. Jelstrup.
A. B. Jones.
W. D. Lambert.
E. W. Lane.
R. M. Leggette.
L. Lek.
J. M. Le Roy.
H. A. Marmer.
F. E. Matthes.

M. Matuyama.
F. G. McEwen.
F. A. Vening Meinesz.
O. E. Meinzer.
A. H. Miller.
R. B. Montgomery.
J. R. Morgan.
W. A. Nelson.
L. L. Nettleton.
J. A. Pounder.
J. H. Pratt.
J. Proudman.
R. Revelle.
K. Rosen.
R. J. Russell.
P. Schureman.
H. Seblatnigg.
L. B. Slichter.
P. Sollenberger.
F. M. Soule.
H. T. Stetson.
V. T. Stringfield.
W. D. Sutcliffe.
H. U. Sverdrup.
C. H. Swick.
C. V. Theis.
W. T. Thom.
T. G. Thompson.
C. Tsuboi.
S. B. Ulories.
T. Wayland Vaughan.
A. Vine.
L. K. Wenzel.
J. E. Willis.
R. M. Wilson.
G. P. Woollard.

D 2. Professor PROUDMAN submitted the Report of the Committee on mean sea-level and its variations. (See p. 74.)

C 2. It was agreed that the Committee should be reappointed with the addition of Professor J. P. Jacobsen. (See p. 50.)

Dr. BOWIE remarked: "It would be of interest if the national levelling nets of European countries could be combined in a single adjustment in order to discover the extent to which mean sea-level at the tidal stations deviates from an equipotential surface. This is a problem of interest to the Associations of Physical Oceanography and Geodesy. The adjustment of the combined nets of Canada and the United States showed that mean sea-level of the Pacific is higher on the average than that of the Atlantic and the Gulf of Mexico."

Dr. VENING MEINESZ stated that this matter would be taken up at a later date.

H 18. In the absence of Dr. La Fond, the paper on "Sea-level and surface temperatures along the coast of California" (see p. 177) was read by Dr. FLEMING.

Dr. MARMER commented on this paper as follows: "The interest of the relations of sea-level to the various oceanographic features given in Dr. La Fond's paper is evident. What I want to call attention to at the present time is to the far-reaching uses to which sea-level data may be put. The geologist assures us that changes in the relation of land to sea of great magnitude have taken place in the past, and that there is every reason to believe that changes in the relative elevation of land and sea are taking place now, but that the rate of change is so slow as to escape detection by geological methods. The variations in sea-level from year to year, if continued for a sufficient number of years, will furnish us definite quantitative data of this rate of change. In another field, too, these sea-level changes furnish data of interest, namely, in climatology—for it is clear that if the climate is becoming more genial, there must follow a recession of the glaciers and a diminution of the ice caps. This added water will make itself evident in the sea-level data."

Professor HELLAND-HANSEN stated: "The seasonal variations in mean sea-level along the California Coast showed minima in about March and November, while on the Atlantic Coast of the United States maxima occurred in the same months. In both cases the variations are connected with variations in the currents. The difference of phase seems to be an important fact which may lead to general conclusions of considerable value."

In the absence of Dr. Eckhardt, his paper on tidal variations was read by Dr. NETTLETON.

D 8. Dr. LAMBERT submitted his "Rapport sur les marées de l'ecorce terrestre."

Professor RUSSELL presented a paper, "Isostatic effects of Mississippi River sedimentation," by himself and H. N. Fisk.

Dr. THOM remarked that he would like an opportunity of hearing and discussing further the interpretation that sedimentation is *inducing* depression—rather than vice versa.

Dr. FIELD made the following comment on this paper: "From the geological point of view it is certainly not yet clear

as to what a geosyncline really is. It seems highly probable, however, that the type of geosyncline of the Appalachians (The Valley and Ridge Provinces) is not a typical geosyncline in terms of origin. It is also interesting to note that the term synclinorium was originally proposed for the deformed sediments which fill the 'geosyncline.' Unfortunately this term has since been misinterpreted so that we now do not have any term for the very phenomena upon which the 'geosyncline' was originally postulated."

Dr. THEIS presented his paper, "Earth tides expressed in fluctuations of water-level in artesian wells in New Mexico."

Mr. LAMBERT commented on this paper as follows: "I have discussed Dr. Theis's computations with him and with officials of the Geological Survey and we do not see eye to eye. The ordinary tidal problem, uncomplicated by aquifers, is difficult enough, as is seen by the references contained in the bibliography of my report. When aquifers are introduced, the complexity is almost inconceivable. I wish to record a dissent from the calculation, though wishing to express my appreciation of the work."

Dr. STETSON commented as follows: "Four methods of observation contribute to the question of tidal deformation in the Earth's crust: (1) geodetic observations for variations of the vertical with respect to stars; (2) tilt measurements; (3) gravimeter data; and (4) changes of water-level in deep wells. The importance of the use of all of these in conjunction is stressed, and also the desirability that those in charge of oil fields should watch for unused wells in different localities where similar observations could be made."

A Joint Meeting of the Associations of Meteorology and of Physical Oceanography

Ninth General Meeting of the Association of Physical Oceanography

Wednesday, 13th September 1939

The Meeting opened at 10.00, when the Chair was taken by Professor T. G. Thompson.

There were present:

R. A. Allen.
H. Arctowski.
D. L. Arenberg.
J. Bjerknes.
Alice L. Brown.
C. E. Buell.
H. R. Byers.
P. E. Church.
Katherine Clarke-Hafstad.
W. Cleet.
V. Conrad.
A. A. Cumberledge.
L. P. Disney.
V. W. Ekman.
W. M. Elsasser.
M. Ewing.
E. P. Finney.
R. H. Fleming.
R. D. Fletcher.
O. H. Gish.
Jewell J. Glass.
Wl. Gorczynski.
G. Van A. Graves.
G. Grimminger.
P. Harvey.
H. D. Harradon.
B. C. Haynes.
B. Helland-Hansen.
E. W. Hewson.
K. Hidaka.
B. Holzman.
W. J. Humphreys.
C. O'D. Iselin.
V. E. Jakl.
J. Keränen.
A. J. Knarr.
L. Lek.
C. M. Lennahan.
J. M. Le Roy.
S. Lichtblau.
H. A. Marmer.
J. W. Mauchly.
G. F. McEwen.
Ingeborg T. Mears.
E. R. Miller.
R. B. Montgomery.

H. Mosby.
J. Namias.
W. A. Nelson.
H. Norinder.
L. F. Page.
J. Proudman.
F. W. Reichelderfer.
R. Revelle.
A. J. Robertson.
G. Rodriguez.
C.-G. Rossby.
Edna Scofield.
H. Solberg.
F. M. Soule.
V. P. Starr.
R. C. Steere.
R. G. Stone.
A. R. Suckley.
H. U. Sverdrup.
B. Swanson.
W. W. Swayne.
T. G. Thompson.
T. Wayland Vaughan.
A. Vine.
R. H. Weightman.
H. Wexler.
P. C. Whitney.
H. C. Willett.
O. R. Wulf.

G II. General discussion on turbulence in the sea and the atmosphere.

2. Dr. H. U. SVERDRUP opened the discussion with "General remarks on turbulence in the atmosphere and the ocean." (See p. 118.)

1. Dr. C.-G. ROSSBY made a contribution.

Professor V. W. EKMAN then said: "For several years Professor Helland-Hansen has continued to establish the previously unexpected intense heterogeneity of horizontal water-layers in the sea, of which Dr. Spilhaus the other day gave us such a striking example. This intense heterogeneity in horizontal directions ought to have suggested the conclusion that the old idea of the dynamical insignificance of lateral mixing in the sea is perhaps not so well founded as has been generally believed. Nevertheless, Dr. Rossby seems to have been the first to arrive at that conclusion, though from another point of view, and to emphasise the probable dynamical importance of lateral mixing. I think that we are greatly indebted to Dr. Rossby for his important remarks on this subject. Though they may make the dynamical oceanography of the future more difficult, they will also make it more consistent with truth."

3. Professor J. PROUDMAN read a paper on "An attempt to measure the frictional forces in a tideway." (See p. 119.)

4. Professor G. F. McEwen read a paper on "Some calculations of vertical velocity and turbulence in the North Pacific near Southern California." (See p. 120.)

G III. General discussion on the interaction between the sea and the atmosphere.

D 6. Dr. H. U. Sverdrup submitted the Report of the Joint Committee on questions of interaction between the sea and the atmosphere. (See p. 87.)

C 8. The Committee was reappointed with the addition of Dr. C.-G. Rossby. (See p. 51.)

Professor H. Arctowski spoke on the variations of the level of the isothermal surface of 0° C. in the Arctic Ocean in their relation to the variations of the distribution of atmospheric pressure.

G III 1·2. Attention was called to a Resolution passed by the International Meteorological Committee in September 1937. (See p. 124.)

Tenth General Meeting of the Association

Thursday, 14th September 1939

The Meeting opened at 11.30, when the Chair was taken by the President, Professor B. Helland-Hansen. Fifteen delegates and guests were present.

H 27. Professor UTTERBACK read his paper on "The spectral distribution and total intensity of daylight in the waters of the Pacific North-west." (See p. 193.)

Dr. SVERDRUP said: "At the Scripps Institution at La Jolla, measurements of submarine daylight have been conducted according to a different plan. In the summers of 1936 and 1937 relative values of submarine illumination were determined by photronic cells. In the summer of 1938 measurements of relative values of transparency were evaluated, and in the summer of 1939 an instrument was designed for determining absolute values in the laboratory. All work has been conducted by Dr. R. T. Young of the Wochester Polytechnic Institute. The measurements of 1938 indicate a relationship between the variations, with depth, of transparency and the other physical characteristics."

Professor UTTERBACK said: "It is my opinion that Dr. Young can succeed in making absolute rather than relative transparency measurements."

Dr. SVERDRUP then said: "The goal is to obtain absolute values of the transparency in the field."

C 7. After some discussion on the proposition that a committee on submarine daylight should be appointed, it was decided that the present time was not opportune for such an appointment.

G III. 1·1. Dr. HIDAKA read his paper on "Wind circulation of water and the inertia terms." (See p. 122.)

On the motions of Professor THOMPSON, Dr. WAYLAND VAUGHAN and Dr. SVERDRUP respectively, Resolutions were passed regarding the oceanographic activities of the U.S. Coast Guard, of the Hydrographic Office of the U.S. Navy, and of the U.S. Coast and Geodetic Survey. (See p. 68.)

B 2. The Auditors submitted their Report on the accounts of the Association for the period 1936–1938. (See p. 72.) The Financial Report was accepted unanimously.

B 4·1. The General Secretary of the Association was appointed to represent the Association on the Committee of Administration and Finance of the Union.

On the motion of Dr. WAYLAND VAUGHAN very hearty votes of thanks were passed to the President, the Acting Vice-President, the General Secretary and the Assistant, for their work in connection with the Association and its General Assembly.

The PRESIDENT responded and then closed the General Assembly of the Association at Washington.

Scientific Committees

Appointed by General Assembly at Washington

Committee on Tides

Chairman : H. A. Marmer.
Secretary : J. Proudman.
Members : A. Courtier, A. Defant, J. E. Fjeldstad, K. Hidaka, J. G. F. Hooykaas, J. P. Jacobsen, S. E. Stenij, H. U. Sverdrup, M. Tenani, H. Thorade, F. Vercelli.

Committee on Mean Sea-level and its Variations

Chairman : R. Witting.
Secretary : J. Proudman.
Members : J. P. Jacobsen, H. A. Marmer, J. D. Nares, J. Vignal.

Committee on Chemical Methods and Units

Chairman : B. Helland-Hansen.
Secretary : J. P. Jacobsen.
Member : T. G. Thompson.

Committee on the Proposed International Survey of the Gulf Stream Area

Convener : B. Helland-Hansen.
Members : D. Cot, A. Defant, J. A. Edgell, C. O'D. Iselin, M. Knudsen.

This Committee has power to co-opt additional members.

Committee on Criteria and Nomenclature for the Major Divisions of the Ocean-bottom

Chairman : T. Wayland Vaughan.

Secretary : President of International Hydrographic Bureau.

Members : D. Cot, J. A. Edgell, B. Helland-Hansen, W. L. G. Joerg, S. Kishindo, P. M. van Riel, G. Wüst.

Hydrographers of Japanese, Netherlands, Norwegian and United States Navies. Direktor der Nautischen Abteilung der Deutschen Marineleitung.

Joint Committee of Associations for Physical Oceanography and for Meteorology on Questions of Interaction between the Sea and the Atmosphere

Convener : H. U. Sverdrup.

Members : C. O'D. Iselin, H. Mosby, C.-G. Rossby, W. Schmidt, J. B. Tait, G. Wüst.

Presidential Address

The International Survey of the Gulf Stream Area

By

B. HELLAND-HANSEN

On behalf of the Association of Physical Oceanography I want to welcome our guests to this meeting. We appreciate the contact and co-operation with other geophysical associations and their representatives. In oceanography we feel the necessity of such contact and co-operation, because the study of the ocean implies the use of theoretical methods of the same kind as those employed in other branches of geophysics and, besides, when working up his material the physical oceanographer very often wants results from, for instance, meteorologists and geodesists. In several respects the themes overlap.

Like other geophysical disciplines oceanography is a truly international subject. The ocean-waters form a continuous medium, and the ocean-currents know of no national borders. The Association of Physical Oceanography certainly has a reason of existence just in its capacity of being international. In this capacity it is confronted with many important tasks for the furtherance of the science it has to represent. I venture to say that our Association has brought about an international co-operation of no small value. The time will not permit me to give you as full an account of our activities during the last three-year period as would have been desirable, and as the activities of the various committees deserve. I must confine myself to deal with a fraction of our activities only, and have selected for this presidential address the international survey of the Gulf Stream Area as my chief theme.

In the previous period, before the Assembly at Edinburgh

in 1936, three committees under this Association were at work, namely, the Committee on Tides, the one on Mean Sea-level and its Variations, and the one on the study of the Raz de Marée. These committees have continued, and have given us several publications based upon very exacting gatherings of observations and their discussion. At the Edinburgh Assembly some new committees were appointed, namely: On Criteria and Nomenclature for the Major Divisions of the Ocean-Bottom; on Chemical Methods and Units; on the Proposed International Survey of the Gulf Stream Area; and, jointly with other Associations, committees on Questions of Interaction between the Sea and the Atmosphere, and on Gravity at Sea.

The various committees have prepared valuable reports for discussion in these days. I feel confident that they prove the *raison d'être* of our Association and the justification of grants given to it, and hope that they will contribute effectively to the advancement of oceanography. As President I feel it my duty and also a great privilege on this occasion to express our gratitude to all those who have taken an active part in the work, and to the many institutions and individuals who have helped us in various ways. I think it appropriate to pay a special tribute to the General Secretary of our Association, Professor Proudman.

For a good many years, physical, dynamical and chemical oceanography has advanced at a noticeable rate. Upon the whole, the theoretical investigations have been ahead of the empirical. To a conspicuous degree this holds good with regard to the dynamics of the ocean. We are confronted with a number of new and important problems which cannot be finally solved until we obtain adequate observations.

Generally speaking, the deep-sea expeditions hitherto have given us a broad geographical view of the ocean. For a proper understanding of the processes going on within the sea we need much more detailed investigations, adapted to the problems to be solved. On this occasion I shall call special attention to the study of a current-system like that of the Gulf Stream.

The current-systems in general seem to be very complicated in many important areas. When shifting in a relatively short time to any considerable degree, they cannot be properly studied unless several ships co-operate. In this connection we may

think of the conditions in the atmosphere. The great progress in our knowledge of the atmosphere and of what is going on there is based on the introduction of synoptic observations at a great number of stations under international co-operation. In oceanography we cannot obtain the same efficiency. The oceanographic field-work is expensive, and it is practically impossible to obtain really synoptic observations from such a number of stations as in many cases would be desirable. We are forced to restrict our demands, but it is obvious that a co-operation of several ships during a single season is many times as efficient as separate and sporadic undertakings. This is eminently the case as far as the Gulf Stream System is concerned.

By investigations in the Norwegian Sea ever since the beginning of our century we have found great variations in space and time within the domain of the Norwegian Atlantic Current, forming a northern part of the Gulf Stream System, and we have emphasized the necessity of numerous stations for the study of relatively strong gradient currents in the sea.* The results from the Norwegian Sea led us to expect similar variations to be of general occurrence in many oceanic areas, so also within the Gulf Stream System of the North Atlantic Ocean.† We have had practically no observations from this area which to any extent might be claimed as synoptical, even within the limits which necessarily have to be drawn for such a claim. Based on my experience from the northern parts of the Gulf Stream System, I, therefore, proposed to the Assembly at Edinburgh in 1936 to make an attempt to carry through an international survey of the Gulf Stream Area between America and Europe by means of many ships. The proposal was adopted by the Assembly, and the Association appointed a committee which had "to draw up a programme for the proposed international survey of the Gulf Stream Area between America and Europe,

* B. Helland-Hansen: "Zur Ozeanographie des Nordmeeres," Publ. de Circ., No. 19, Copenhagen, 1904.

Bjørn Helland-Hansen and Fridtjof Nansen: "The Norwegian Sea," Rep. Norw. Fish. and Marine Invest., Vol. II, No. 2, Bergen, 1909.

B. Helland-Hansen: "New Investigations in the Norwegian Sea," Ass. Intern. d'Oceanogr. Physique, Proc. Verb., No. 2, Liverpool, 1937.

† According to modern terminology the Norwegian Sea is distinct from the North Atlantic Ocean, being separated from the latter by the submarine ridges between Scotland, the Faeroes, Iceland, and Greenland.

and to take steps towards securing the necessary co-operation." As members of the Committee representatives were elected from Denmark (Professor M. Knudsen), France (Director D. Cot), Germany (Professor Defant), Great Britain (Admiral Edgell), the United States (Professor Iselin), and from Norway myself, who was made Convener of the Committee.

After some attempts to draft a definite programme for the survey, I found it necessary to make some additional studies of the general character of the variations. Such preliminary, but at the same time fundamental investigations, were undertaken in the Norwegian Sea in the summer of 1937 by means of three small research vessels from Norway. A great number of simultaneous observations were made from the vessels at anchor near and within the border of the Norwegian Atlantic Current. The observations again proved that the variations in the oceanographic situation may be very great indeed. The observations indicated different kinds of variations: Lateral displacements of the currents, passing eddies, and probably also a succession of large, mutually somewhat heterogeneous, bodies of water. The variations found could only to a small degree be accounted for by internal waves. These results made it the more advisable to make similar preliminary studies of the variability within the Gulf Stream Area of the open North Atlantic itself. It appeared best to attempt this in the early summer of 1938, provided a few ships with all the necessary equipment and with a trained staff of assistants and observers could be available. So as not to render difficult the participation of many ships in a final survey later on, it seemed inadvisable to call upon a wider co-operation now. I came to the conclusion that the preliminary investigations ought to be made by means of two or three ships in the central part of the North Atlantic, north of the Azores, and by other ships in the north-eastern area, west of the British Isles and northwards to Iceland. In the central area, sections should be worked along nearly parallel lines with a short distance between the sections, and with stations approximately every twenty nautical miles along the sectional lines. For some time during the operations one of the ships should be anchored on the Telegraph Plateau, where previous soundings had shown bottom depths of less than 2000 metres.

The German authorities were willing to send a ship (the *Altair*) to the Azores Area for co-operation with the Norwegian research vessel *Armauer Hansen* in accordance with the proposed plan. The Danish and Scottish authorities were willing to carry through the programme with regard to the north-eastern area. In this area the distances between the sections were relatively large because a general reconnaissance of the whole area was wanted, but along the sectional lines the stations upon the whole were taken every twenty nautical miles. Conjointly with the other expeditions, investigations were made in the Denmark Strait between Iceland and Greenland by the Icelandic Fishery Inspection ship *Thor*.

At the same time investigations were made in the western half of the ocean by the *Atlantis* from the Woods Hole Oceanographic Institution, which operated between America and Bermuda, and by the *General Greene* from the United States Coast Guard, which worked a section through the Gulf Stream south of the Newfoundland Banks.

In this way investigations were brought about by means of seven ships from six countries operating within two months in the summer of 1938, from the middle of May to the middle of July. The work has resulted in serial observations of temperature and salinity at 482 stations with nearly 7000 points of observations. These figures do not include observations of temperature and salinity (88 series) at the anchor station occupied by the *Altair*. At this station many current-measurements also were made at various levels. In addition to the serial observations at the stations, more than 3000 observations of temperature and a smaller number of salinity determinations were made by the *Altair*, *Armauer Hansen*, and the French ship *Carimaré*, which was stationed in the North Atlantic for a meteorological survey in connection with transatlantic flying. A co-operation was established between this ship and the two other ones. The *Carimaré* received observations by wireless from the *Altair* and the *Armauer Hansen*, and on her side gave weather forecasts to the oceanographic ships and procured temperature observations and water samples from the sea-surface west of the Azores in June. Many meteorological observations were made by all oceanographic research ships and, besides,

aerological observations with radio meteorographs from the *Altair*.

The material of oceanographic observations from the short season of operation in 1938 in the North Atlantic is many times as large as has been procured from any single season before. The final working-up of the material will require a longer time

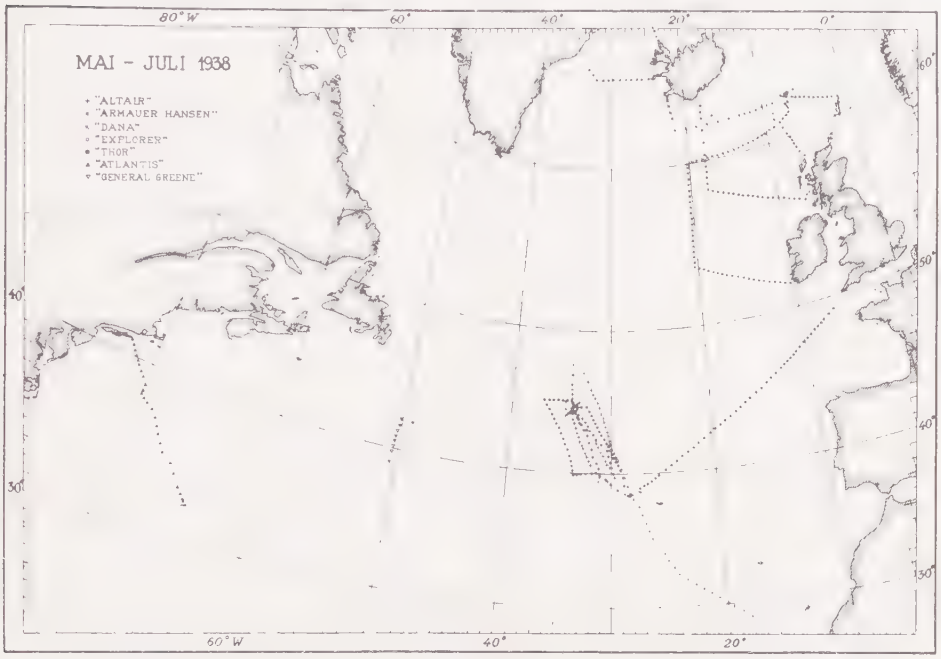

FIG. 1.—The stations.

than we have had available. The primary work resulting in tables of corrected temperatures, salinities, etc., has required the greater part of the time since the observations were made. In April 1939, oceanographers in charge of the observations from the European ships met at Bergen and discussed the results conjointly. Professors Defant and Wüst from Germany, Dr. Tait from Scotland, Dr. Thomsen from Denmark, and Dr. Mosby and myself from Norway, then worked together during a fortnight and agreed upon the further procedure. Although a final report cannot be presented here, the working-up of the material has advanced so far that I hope it may serve its purpose: To give a rational basis for the programme of the intended chief

survey, which, it is to be hoped, can be carried through in the summer of 1941.

Especially in the area north of the Azores it was important to work as quickly as possible with the chief aim in view: A

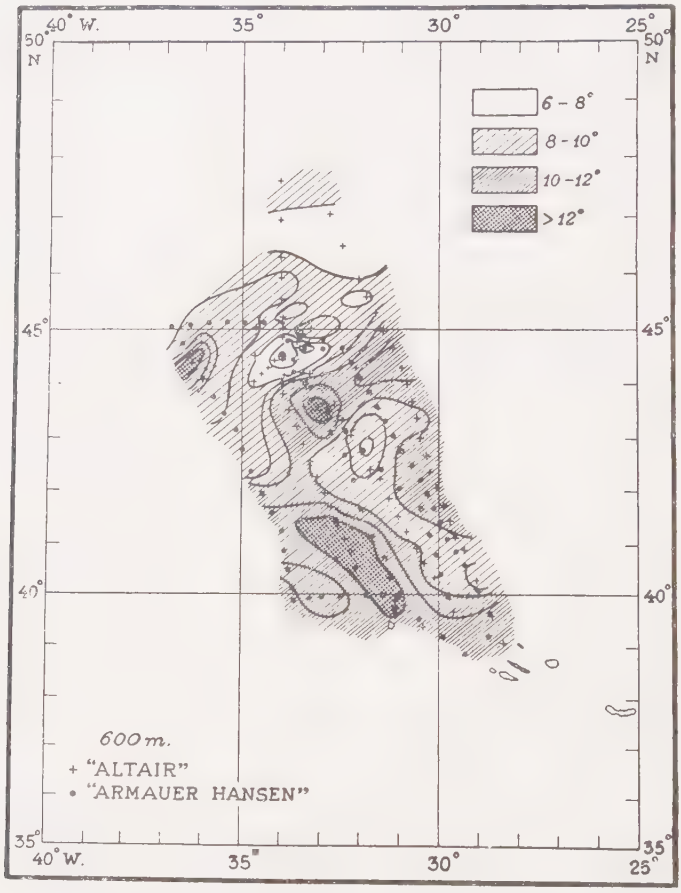

Fig. 2.—The distribution of temperature at 600 metres in the region north-west of the Azores, June 1–26, 1938.

study of the variations of the currents from place to place. The oceanographic observations therefore were limited to observations of temperature and salinity alone, with additional current-measurements at the anchor station. Under headway numerous echo-soundings were made from the *Altair*. They have led to a revision of the bottom charts and a new view of the bottom configuration in several parts of the Azores Region.

The waters north and north-west of the Azores form a central part of the Gulf Stream System. The observations now made show local variations which to many oceanographers will be quite amazing. When demonstrating some of these variations I must call attention to the fact that our charts and sections are constructed without any attempt to correct for possible variations with time. At our present state of knowledge we cannot make such corrections in any satisfactory way. It may be taken for certain, however, that time-variations in general do not essentially alter the picture of local variations in the Azores Area as shown by our diagrams.

Figure 2 represents the distribution of temperatures at a depth of 600 metres below the surface. Above the Telegraph Plateau, where now a volcanic cone named after the *Altair* has been discovered, we find an area with temperatures below 7° C., while, for instance, we find an area with its centre about 75 nautical miles farther south-east, with temperatures about 12° C. We have every reason to believe that the area with relatively very low temperatures around the Altair Cone forms a practically permanent feature, indicating a marked cyclonic movement around the cone. Similar variations to those found at 600 metres were also found at other levels above and below.

Figure 3 illustrates the distribution of maximum salinities at high levels, between 25 and 100 metres. The chart (constructed by Professor Wüst) indicates a division of the Gulf Stream waters in three branches in this special region near the central ridge of the North Atlantic.

Figure 4 gives a reproduction of four nearly parallel sections in the direction south-east to north-west through the Azores Area. The mean distance between the sections is approximately 55 nautical miles. The large windings of the curves of equal salinity and of equal temperature cannot be explained by internal waves. They indicate a complicated system of currents in different directions—partly individual branches of the "Gulf Stream" with counter-currents in between, and partly eddies.

In connection with these graphical representations I may call attention to the close correlation between salinities and temperatures, and to the important fact that in this respect there is a perfect agreement between the German and Norwegian

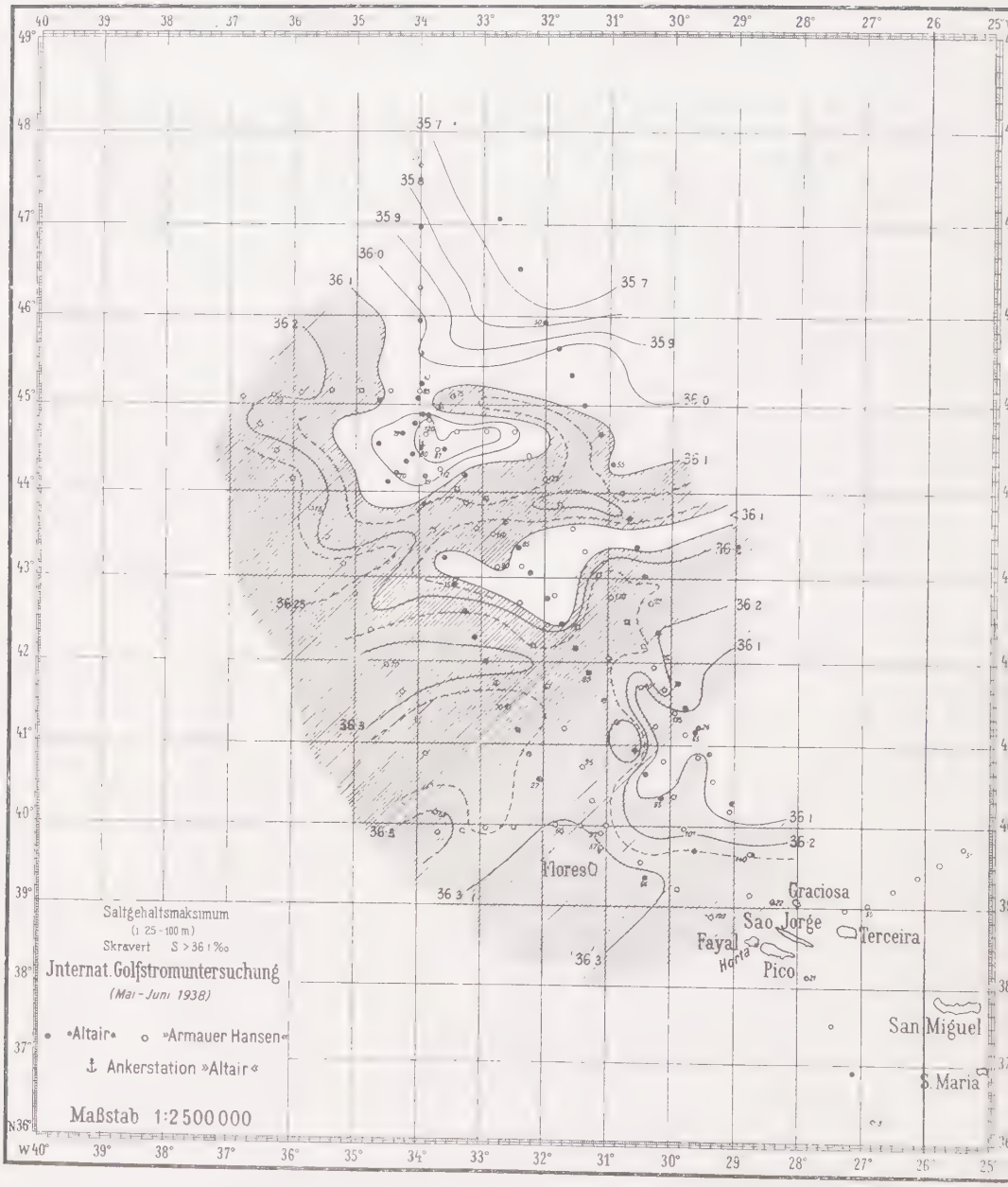

FIG. 3.—The maximum of salinity observed in water layers between 25 and 100 metres in the region north-west of the Azores in June 1938.

FIG. 4.—The vertical distribution of salinity and temperature in four nearly parallel sections from the Azores (the right-hand side of each section) towards north-west.

[Isohalines are drawn for every 0·1‰ salinity and isotherms for 5, 10, 15 and 20° C.; the ratio between vertical and horizontal scale is 400 : 1; the sequence of the sections reckoned from west to east is (*a*) upper left, (*b*) lower left, (*c*) lower right, (*d*) upper right.]

observations. Two of these sections are constructed from temperatures determined by the German expedition and salinities determined at the Institut für Meereskunde in Berlin, while the two other sections represent observations made by the Norwegian expedition together with analyses of salinity made at the Geophysical Institute of Bergen. The determinations thus far have been quite independent of each other in the two countries. The juxtaposition of the sections shows everywhere a nearly perfect coincidence between the isotherm of 15° C. and the isohaline of 36·0‰. In the most westerly section (fig. 4*a*) the isotherm of 10° C. runs together with the isohaline of 35·3‰. In the three other sections we find the same accordance existing in the northern part of the area, while in the southern the 10°-isotherm runs along the 35·4-isohaline. This is a good example of the conformity of oceanographic observations internationally.

In this connection I may also point out that in various places there is a striking accordance between some characteristic variations in bottom topography and variations in the water-masses above. This is especially conspicuous at the locality of the Altair Cone. Many years ago we saw from observations in the Norwegian Sea rather a close resemblance between charts of bottom topography and charts representing the distribution of temperature and salinity in the upper water-masses. As is well known to oceanographers, Professor Ekman, by theoretical studies has found some rules showing an interrelation between variations in the bottom depth and the gradient currents. In many cases the local variations in the water seem to be closely connected with variations in bottom topography, which —as we know—has proved to be much more complicated than previously assumed.

In areas with local variations like those found in the region north of the Azores, the necessity of numerous stations is evident. Figure 5 may serve to illustrate the difference of results obtained by a close and an open network of serial observations. In the upper section the distance between the stations is about 20 nautical miles. In deep-sea work a distance of about 60 nautical miles has previously been considered quite satisfactory. The lower section in fig. 5 shows how the section would have looked if only every third station reckoned from the northernmost one

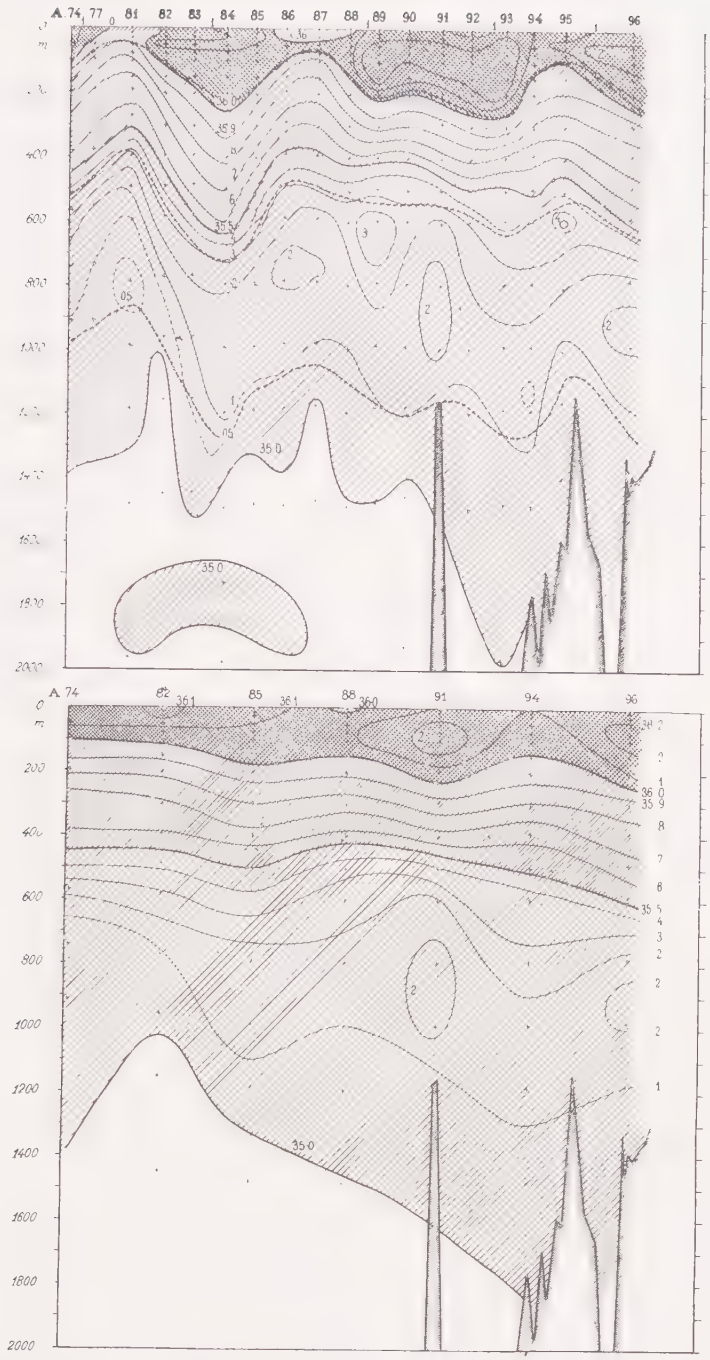

FIG. 5.—The upper figure is the same as (c) in fig. 4, the distance between the sections being about 20 nautical miles; the lower figure illustrates how the same section would have been constructed if observations merely from every third station (distance about 60 nautical miles) had been available.

(to the left) had been taken. A comparison between the two stations immediately shows how misleading conclusions may be drawn from an open net of stations. Applying dynamical

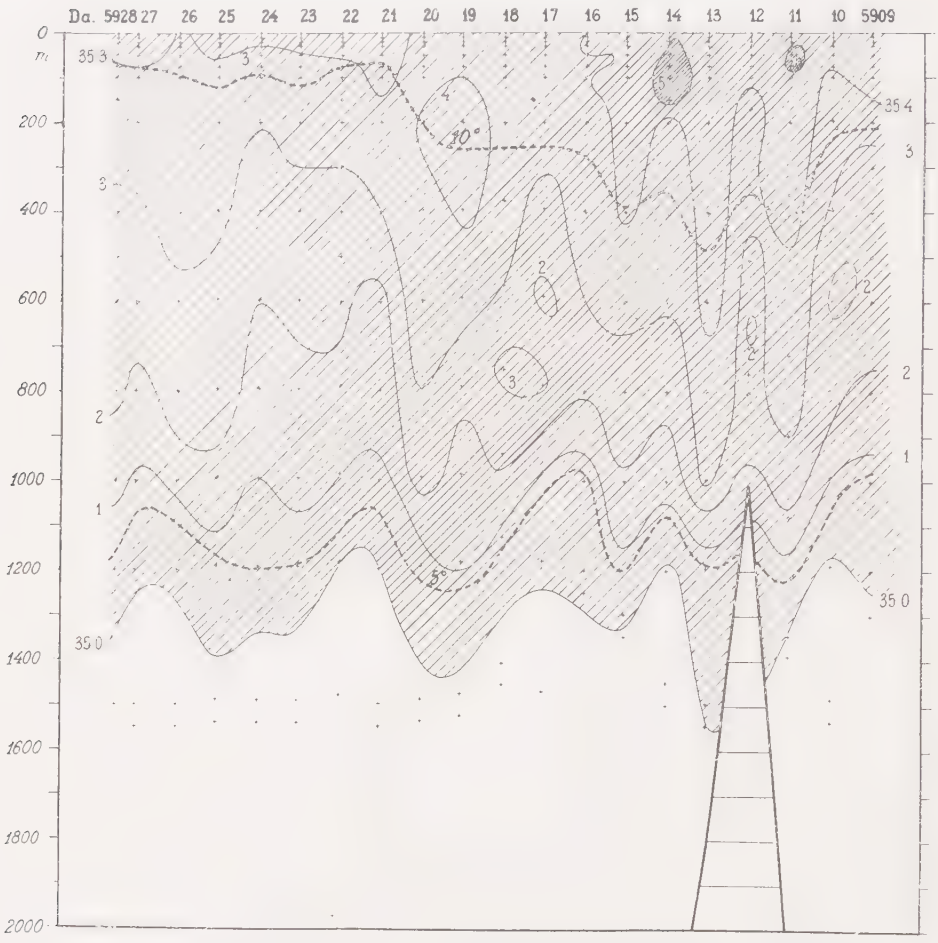

FIG. 6.—The section along 20° west longitude from about 54° north latitude (the right-hand side of the figure) to 60° north latitude.

principles to the interpretation of the sections, we see that the shifting between currents and counter-currents is scarcely to be traced from the incomplete series of observations.

Similar conditions were found also by our investigations in the north-eastern part of the North Atlantic.

Figure 6 represents a vertical section (drawn by Dr. Thomsen)

from the *Dana* expedition in a south-north direction along twenty degrees of longitude from a region west of the British Isles.

Fig. 7.—Draft of a salinity-chart for 400 metres in the north-eastern part of the North Atlantic.

Figure 7 shows an attempt (by Dr. Tait) at drafting a horizontal chart for 400 metres, as a demonstration of the way in which charts are commonly constructed in physical

oceanography. We are fully aware that such a combination of observations with long distances between the sections is not admissible in regions of great local variations.

After the experience now gained it seems evident that a programme for a more detailed study of the Gulf Stream System in such areas as the central and north-eastern part of the North Atlantic should be based on the following general principles:—

1. A dense network of observations, not merely stations at short intervals along the sectional lines, but also short distances between the sections. The sections ought to be worked twice at least during the time to be agreed upon for the co-operation.

2. The number of ships engaged in the survey being limited, relatively small areas only can be surveyed in one season. Two or three ships ought to co-operate in each area, working sections in belts of a reasonable length and width. The areas have to be selected according to their representative character as well as to the radius of action of ships engaged in the survey and to the opportunity of calling at convenient harbours.

3. If possible, observations ought to be made at anchor stations in suitable localities within the areas selected.

Previous expeditions in the North Atlantic have given us a first reconnaissance of the Gulf Stream System, but a deeper insight into the conditions can hardly be expected from a continuation of investigations in the customary way. Scattered observations can scarcely add to our knowledge in any essential degree. In my opinion it is not rational to send out new expeditions for studying complicated current-systems in regions from which a general orientation already is procured, if the stations are distributed as far and wide between the stations as has hitherto been the case. In such regions we want, so to say, intensive and not extensive explorations. With due reserve and in analogy with an expression used in climatology we might even speak of a micro-oceanography. The time is now ripe to carry out intensive observations, and the Gulf Stream System bids us a very suitable and, at the same time, important object of research. We can define the problems, and with the modern instruments and methods we possess satisfactory means of attacking them. In this connection I may mention the following points:—

We know that a definite correlation between temperatures and salinities exists in most oceanic areas. When taking ordinary serial observations, say, every twenty nautical miles, we obtain further details with regard to the distribution of mass and pressure without appreciable loss of time if between the stations we may have quick-run registrations of temperature to a considerable depth below the surface. In 1935 Professor Rossby reported on a thermograph which he had used down to 50 metres. Afterwards Professor Spilhaus has constructed a bathythermograph giving quick-run registrations down to a depth of about 300 metres. At the Geophysical Institute of Bergen we have also worked on this technical problem. Some years ago we built an apparatus which was, however, rather complicated. Later on Dr. Mosby made attempts to utilize a very simple mechanical principle for a self-recording thermograph to be used to greater depths, about 2000 metres. We made numerous experiments with this new thermo-sounder on the *Armauer Hansen* Expedition last year, and the results were very promising.

For many years the Gulf Stream problem has been of great interest to many people, but in spite of numerous investigations in the course of time it is as much of a problem to-day as it ever has been. In dealing with it we encounter some most fundamental questions in general: What is the inner mechanism of the ocean? What about the stability of the currents? What is the effect of turbulence of different scales, from the irregular movements of individual water-particles to the interplay of huge bulks of water? What about the occurrence of eddies and the causes of their formation? And so on. To this may be added the importance of a systematic study of the interaction between the sea and the atmosphere, with regard to energy and mass.

I am fully convinced that very large steps forward may be taken in our understanding of the ocean if a detailed survey will be made with the assistance of many countries and many ships in peaceful and loyal co-operation.

General Resolutions

Adopted by the General Assembly of the Association

on 14th September 1939

1. Resolved that the International Association of Physical Oceanography express its appreciation of the important additions to knowledge of the oceans made by the Navy of the United States of America by putting at the service of scientists submarines for measuring gravity at sea, by running many lines of echo-soundings over areas of sea-bottom, the configuration of which was previously unknown, by compiling data for and publishing bathymetric charts and charts of sea-surface temperatures, winds and currents, and by aiding oceanographic institutions in procuring records of sub-surface conditions in the sea at many places.

Resolved further that a copy of this resolution be sent to the President of the United States, the Secretary of the Navy, and the Hydrographer of the Navy.

2. Resolved that the International Association of Physical Oceanography express its appreciation of the scientific value of the oceanographic investigations carried out by the United States Coast and Geodetic Survey, in the accurate delineation of the sea-bottom as shown in the coastal charts, and in the securing of data on tides and sea-level.

Resolved further that a copy of this resolution be sent to the President of the United States, the Secretary of Commerce, and the Director of the Coast and Geodetic Survey.

3. Resolved that the International Association of Physical Oceanography express its appreciation of the scientific value of the oceanographic investigations conducted by the International Service of Ice Observation and Ice Patrol in the regions of the Grand Banks of Newfoundland, the Labrador Sea, Davis Strait, and Baffin Bay; that it commend the United

States Coast Guard for the manner in which such work has been carried out in the past; and that it express the earnest hope that the work will be continued and extended in the future.

Resolved further that a copy of this resolution be sent to the President of the United States, the Secretary of the Treasury, and the Commandant of the Coast Guard.

Administrative Reports

Report of the General Secretary for the Period 1936-1939

Since the General Assembly at Edinburgh in 1936, the following publications have been issued or are in the press:—

Procès-Verbaux

No. 2. General Assembly at Edinburgh, September 1936.

Publications Scientifiques

No. 3. Bibliography on Tides and certain kindred matters. (Fourth instalment).

No. 4. Phil E. Church, "Temperatures of the Western North Atlantic from thermograph records."

No. 5. Monthly and annual mean heights of sea-level, up to and including the year 1936.

The Executive Committee has made a grant of £50 to Dr. A. Ångström, to enable him to make an experimental investigation of the possibilities of standardising photo-electric cells used in oceanography by means of solar radiation.

Expenditure by the various scientific committees, in so far as it was not authorised at the Edinburgh General Assembly, has been approved in advance by the Executive Committee. Details are given in the Financial Report.

(The above Report was unanimously adopted by the General Assembly of the Association on 7th September 1939.)

Financial Report for Period 1936-1938

A summary of the Income and Expenditure for the period 1st January 1936 to 31st December 1938, and the Balance Sheet for 31st December 1938, are given in the accompanying tables.

Income.

	1936. Swiss Gold francs.	1937. Swiss Gold francs.	1938. Swiss Gold francs.
By General Secretary of Union .	13061.90	12997.02	9941.12
By sale of publications . .	..	2.26	13.91
By Bank Interest . . .	213.66	235.54	275.39
	13275.56	13234.82	10230.42

Expenditure.

	1936. Swiss Gold francs.	1937. Swiss Gold francs.	1938. Swiss Gold francs.
Grants-in-aid :			
M. Knudsen	5263.54	..	..
J. W. Sandström . . .	3759.64	..	..
C. L. Utterback . . .	3045.80	..	..
A. Ångström	..	751.94	..
Commission pour l'Étude des Raz de Marée . . .	..	..	678.00
Work on Mean Sea Level . .	761.72	451.16	595.16
Work on Chemical Units . .	..	..	1503.85
Publications :			
Publication Scientifique No. 3 .	407.92	..	..
Procès-Verbaux No. 2 . .	..	1118.86	..
Publication Scientifique No. 4 .	..	518.82	..
Meetings :			
Travel, etc.	937.66	360.92	255.57
Bureau :			
Secretarial Assistance . .	833.33	160.16	645.16
Printing	826.00	253.39	..
Stationery and supplies . .	111.22	39.92	44.33
Postage and carriage . .	109.25	179.93	88.97
Miscellaneous	19.43	5.23	7.96
	16075.51	3840.33	3789.00
Balance . .	2799.95	9394.49	6441.42
	(Dt.)	(Cr.)	(Cr.)

BALANCE SHEET, 31st DECEMBER 1938.

Assets.

	Swiss Gold francs.
Cash at Martins Bank, Liverpool	59100.40
Cash in hand of Secretary of Association	75.19
	59175.59

Liabilities.

	Swiss Gold francs.	
Cash in bank and hand on 1st January 1936, *less* .	46566.03	
Amount due to Raz de Marée on 1st January 1936	426.40	
		46139.63
Income and Expenditure Account :		
1936 deficit		2799.95
1937 credit		9394.49
1938 credit		6441.42
		59175.59

The Assets on 1st January 1936, viz., £3096, 10s. 11d., and the amount then due to the Commission pour l'Étude des Raz de Marée, viz., £28, 7s. 1d., were shown in the Accounts submitted in 1936 as 47067.50 and 430.98 Swiss francs respectively. The Assets on 31st December 1938 were £3934, 17s. 8d., and in drawing up the Balance Sheet, £1 has been taken as 15.0385 Swiss Gold francs.

On 31st December 1938 the Association was committed to certain expenditure which was not then actual and which was not balanced by corresponding prospective expenditure on 1st January 1936. This is due to the activity of certain committees, and the chief items are as follows:—

Committee on Mean Sea Level and its variations :		
Printing	7500.0	Swiss Gold francs.
Committee on Chemical Methods and Units :		
Travel	3007.7	,, ,,
Printing (say)	12500.0	,, ,,
Committee on Survey of Gulf Stream area :		
Travel and Secretarial assistance .	3007.7	,, ,,
Printing	7500.0	,, ,,
	33515.4	

The total effective expenditure during the period was therefore 57220.24 Swiss Gold francs; apart from the grants to individuals, it was 44399.32 Swiss Gold francs. The expenditure on the work of the Association itself has therefore exceeded the total income for the period by 7658.52 Swiss Gold francs.

J. PROUDMAN (*General Secretary*).

We have examined the accounts of the Association of Physical Oceanography for the period 1936 to 1938 inclusive, and we hereby certify that the said accounts are in order.

T. WAYLAND VAUGHAN,
C. O'D. ISELIN,
Auditors.

WASHINGTON, 12*th September* 1939.

(The above Report was unanimously adopted by the General Assembly of the Association on 14th September 1939.)

Reports of Committees

Report of Committee on Tides

The work of the Committee has been carried out by correspondence and has consisted in the preparation of a fifth instalment of the "Bibliography on Tides and certain kindred matters."

This instalment gives references to publications in all groups issued during the years 1935–1937 inclusive. It will be published as a *Publication Scientifique* of the Association.

(The above Report was unanimously adopted by the General Assembly of the Association on 8th September 1939.)

Report of Committee on Mean Sea-level and its Variations

The work of the Committee has been devoted to the collection, tabulation and publication of data on the observed heights of sea-level. Active collaboration has been maintained with the International Hydrographic Bureau at Monaco, the *Conseil international pour l'exploration de la mer* at Copenhagen and many national authorities. To all these bodies the Committee expresses its cordial thanks.

A volume entitled, "Monthly and annual mean heights of sea-level, up to and including the year 1936," is being published as *Publication Scientifique No.* 5 of the Association.

At the meeting of the *Conseil permanent international pour l'exploration de la mer*, held at Copenhagen in May 1938, the following resolution was adopted:—

"In view of the fact that the 'Association Internationale d'Océanographie Physique' has undertaken, as part of its normal activity, to publish lists of monthly and annual mean heights of sea-level observed at stations which are representative of world-wide conditions, it is recommended that the

publication of the sea-level tables in the *Bulletin Hydrographique* be discontinued from the year 1937, and that the sea-level material collected for publication be transmitted to the General Secretary of the 'Association Internationale d'Océanographie Physique' for inclusion in the publications of that body." (*Rapp. et Proc. Verb.*, Vol. CVII, No. 1, p. 38.)

A pamphlet entitled, "Monthly and annual mean heights of sea-level, 1937," was issued at the beginning of 1939. This is intended to be the first issue of a series which shall appear annually. It is the recommendation of the Committee that every fifth year, the printed lists for the five preceding years, together with any lists which have not previously been published by the Association, shall be bound together and issued as a *Publication Scientifique* of the Association.

(The above Report and recommendations were unanimously adopted at the Joint Meeting of the Associations of Geodesy, Meteorology, Oceanography and Hydrology on 12th September 1939.)

Report of Committee on Chemical Methods and Units

The Committee, consisting of Messrs B. Helland-Hansen, Chairman, J. P. Jacobsen, Secretary, and Thomas G. Thompson, was appointed at the meeting of the "Association d'Océanographie Physique" at Edinburgh in 1936, and gave its first report (1) at that meeting. This report contains the Committee's proposals on the preparation of a monograph on the determination of the different constituents of sea-water, on the scheme of units to be used when indicating the contents of the constituents and on the elaboration of conversion tables. The proposals of the Committee were unanimously adopted by the General Assembly of the Association, and the Committee has since then taken up its work according to the adopted proposals.

The Committee has elaborated working schemes for the determination of some of the constituents, and the Secretary has prepared a Report entitled, "Nomenclature, Units and Conversion Tables." Details concerning the work have been discussed by correspondence. Thanks to a grant of £200 from

the Association, the Secretary has had the opportunity to visit Prof. Thomas G. Thompson in Seattle to discuss with him verbally the details of the work. The following items are agreed upon within the Committee:—

1. The work on the preparation of the monograph is to be continued. It is supposed that a part of it may be ready for printing before 1940.
2. The report on "Nomenclature, Units and Conversion Tables" is to be published by the Association.

The question of nomenclature and units for indication of the concentration of constituents of sea-water has been discussed by various oceanographers. In 1933, Neal M. Carter, Erik G. Moberg, Tage Skogsberg, and Thomas G. Thompson (2) made recommendations. Other recommendations have also been made by L. N. Cooper (3) and K. Kalle (4). In 1934, a Committee, consisting of K. Buch (Finland), J. P. Jacobsen (Denmark), B. Schulz and H. Wattenberg (Germany), was appointed by the *Conseil international pour l'exploration de la mer* for consideration of the chemical nomenclature to be used in its publications. This Committee has collaborated with various scientists, viz., W. R. G. Atkins (Plymouth), N. W. Rakestraw and H. B. Bigelow (Woods Hole), K. Kalle (Hamburg), Thomas G. Thompson (Seattle), and Neal M. Carter and H. B. Hachey (Canada), and delivered its final Report (5) in 1938, which was adopted by the *Conseil*.

The groups that hitherto have given their recommendations are all represented in the International Association, and, furthermore, this organisation comprises all the countries that have not hitherto taken part in the deliberations. The Committee feels, therefore, that all attempts at standardization should properly be made for final recommendation and adoption by this Association.

As stated in the first Report from the Committee appointed in 1936 by the International Association of Physical Oceanography, it was foreseen that a complete, uniform scheme for indicating the concentration of the constituents in sea-water could scarcely be agreed upon among all oceanographers. In submitting this Report on units and procedures, enough lati-

tude has been given to the recommendations so that they should be acceptable to the great majority. It has been the aim of the Committee to secure for its proposals as world-wide an agreement as possible. The above-mentioned Report, "Nomenclature, Units and Conversion Tables," contains the expressions and units that preferably are to be used. Alternatives for the expressions and the units are proposed in some cases. The Report also contains several tables for conversion calculations. Such calculations may be necessary:

1. For the work in the laboratories when the results are prepared for publication.
2. For the comparison of results that are published by using different expressions and units.
3. For the calculation of the ratio of the concentration of a constituent to the chlorinity.

It is the hope of the Committee that such calculations may be facilitated by the use of the Tables. For assistance in the elaboration of the Tables, Dr. Jacobsen has received a grant of £100 from the Association.

Bibliography.

(1) Association d'Océanographie Physique. Proc. verb. No. 2, page 56, 1937.
(2) Proceedings of the Fifth Pacific Congress, Victoria and Vancouver, B.C., Canada, 1933.
(3) Journal du Conseil. Vol. VIII, page 331, 1933.
(4) Annalen der Hydrographie, 1935, page 18.
(5) Conseil permanent pour l'Exploration de la Mer. Rapp. et Proc. verb. Vol. CVII, 3ième partie, page 3, 1938.

(The above Report and its recommendations were unanimously adopted by the General Assembly of the Association on 7th September 1939.)

Committee on Chemical Methods and Units

Meeting at Washington, on 9th September 1939 at 10.00

There were present B. Helland-Hansen (in the Chair) and T. G. Thompson, together with L. H. N. Cooper, R. H. Fleming, J. Proudman and N. W. Rakestraw.

It was agreed to recommend:

(1) That the term "chlorinity" should be used in reference to one kilogramme of sea-water.

(2) That the term "chlorosity" should be used in reference to one litre of sea-water.

(3) That those parts of Part I. of the Manual prepared by the Committee, which contained matters on which there might not be complete agreement, should be manifolded and sent to a number of experts for comments.

(The above Report and its Recommendations were unanimously accepted by the General Assembly of the Association on 11th September 1939.)

Report of the Committee on the Proposed International Survey of the Gulf Stream Area

Convener : B. Helland-Hansen (Norway).
Members : D. Cot (France).
A. Defant (Germany).
J. A. Edgell (Great Britain).
C. O'D. Iselin (United States).
M. Knudsen (Denmark).

According to the resolutions agreed upon at the General Assembly of the International Association of Physical Oceanography at Edinburgh in September 1936, the "Gulf Stream Committee" appointed by the Association had "to draw up a programme for the proposed international survey of the Gulf Stream Area between America and Europe and to take steps towards securing the necessary co-operation."

It is evident that the proposed survey will be such a great undertaking that the programme must be very carefully prepared and a sound foundation laid before the various countries be invited to join and the necessary co-operation upon a large scale secured. Shortly after the Edinburgh meeting several alternatives were worked out regarding areas to be investigated and routes of co-operating ships. It proved, however, that some additional investigations into the variations of the currents both in time and space were desirable before criteria for the various alternatives could be obtained and a definite programme fixed.

The proposal for an international survey of the Gulf Stream area was mainly based upon experiences from the Norwegian Sea, where variations within the regions more or less occupied by the Norwegian Atlantic Current (a part of the Gulf Stream System) had proved to be very great. It was assumed that similar variations (in time and space) are likely

to occur in the Gulf Stream area of the Atlantic too. In order to obtain a safer basis for a detailed programme of the proposed survey of this area, it was desirable at first to make some additional studies of the general character of the variations. To begin with, studies of this kind were made in the Norwegian Sea in the summer of 1937. The research ships ARMAUER HANSEN (The Geophysical Institute) and JOHAN HJORT (The Director of Fisheries in Norway) and a hired fishing vessel HUSELAND took part in the research. The ships were anchored in a triangle in three different localities near the Continental Slope off Western Norway, and simultaneous observations of temperature and salinity, partly also current measurements, were undertaken. Very considerable variations were observed, indicating occasional lateral displacements of the Norwegian Atlantic Current, passing eddies, and possibly a succession of large, mutually heterogeneous bodies of water. The variations observed are only, to a small degree, accounted for by internal waves.

After the results thus obtained, it seemed the more advisable, by means of two or three ships, to make some preliminary studies of the magnitude of variability—locally and with time—in the Gulf Stream area in the central parts of the North Atlantic. It was advisable to do that as soon as possible provided that two or three ships, with all the equipment necessary and a trained staff of scientists and observers, would be available for such a special task. So as not to render difficult the participation of many ships in a final survey later on, it seemed inadvisable to call upon a wider co-operation at that stage.

Having reason to believe that Germany might be ready to enter into a co-operation of this kind together with Norway, from whence the ARMAUER HANSEN might be sent out, the convener of the Committee went to Berlin in October 1937 in order to have the question settled. At a conference in the "Institut für Meereskunde" with Professors DEFANT and WÜST and representatives from other authoritative bodies, he submitted his views to those present and set forth the following plan: The ships taking part in the preliminary studies of the variability within the Gulf Stream area of

the central North Atlantic should meet at Horta (Fayal, the Azores) in the early summer of 1938, the definite date to be fixed later on. Then the ships should work simultaneously a series of sections with about 20 nautical miles between the stations, in the sea N. and N.W. of Fayal, preferably as far north as the border of the main part of the "Gulf Stream," after which they should return to Horta. Based upon the results obtained, the position of the anchor station should be fixed, a suitable locality probably being the Telegraph Plateau, where previous soundings show bottom depths of less than 2000 metres. Together with oceanographic observations, regular meteorological observations should be taken. The plan was ultimately adopted by the German representatives present at the conference, and the work of preparation started at once. The essential preparatory arrangements, financial and technical, having been made, a second conference was held at Berlin in February 1938 and the necessary details agreed upon. Amongst other things it was resolved as follows: The German Navy Direction, represented by Rear-Admiral Dr. F. Conrad, placed a ship ALTAIR at disposal for the investigation, the ship being rebuilt for research work. The ALTAIR, which at first had to go to the Canary Islands, should work a section from these islands to the Azores in the latter half of May 1938. At the same time the ARMAUER HANSEN should work a section from the English Channel to the Azores. The ships should meet in Horta on 31st May. The investigations N. and N.W. of Fayal should be pursued according to the plan agreed upon at the meeting in October 1937. The work in this area should go on during four weeks in June. Besides other meteorological observations, daily radio-sonde ascents should be undertaken from the ALTAIR. Both ships would be fitted with radio stations.

Under the auspices of Cimaé (Commission Internationale de Météorologie Aéronautique) the French ship CARIMARÉ was stationed in the North Atlantic for a meteorological survey in connection with transatlantic flying. It was opportune to try to have a co-operation established between the oceanographic ships and the CARIMARÉ, and in November 1937 steps were taken towards that purpose. Dr. R. Habermehl,

President of the Atlantic Committee of CIMAÉ, took part in the second conference in Berlin, and through him as intermediary the co-operation was realized. The CARIMARÉ should receive observations by wireless from the ALTAIR and ARMAUER HANSEN, and should on her side give weather forecasts to the oceanographic ships and procure temperature observations and water samples from the sea surface west of the Azores in June.

The programme was successfully carried through. The two oceanographic ships met in Horta on 29th May: The ALTAIR with Professors DEFANT (leader) and WÜST, four assistants for oceanography and three meteorologists, and the ARMAUER HANSEN with Professor HELLAND-HANSEN (leader), Dr. H. MOSBY and three assistants. After their first survey N. and N.W. of Fayal, the ships met in Horta again. The ALTAIR had made echo-soundings on the Telegraph Plateau, and in some places had found considerably smaller bottom-depths than had been anticipated from previous soundings. The ship went from Horta to 44° 33′ N. Lat., 33° 58′ W. Long., where she anchored at a depth of about 1100 metres, and worked from the 16th to 20th May 88 series of hourly temperature and salinity observations, from the surface to 800 metres, and made numerous current measurements at the same time. Meanwhile the ARMAUER HANSEN worked a section from Fayal to the anchor station, and then anchored at a short distance from the ALTAIR in order to release this ship. However, a gale had commenced to blow, and it increased so much that both ships had to heave to after some hours. The weather and the heavy sea did not improve during the following two or three days, and as the weather situation was likely to remain unaltered in this locality for some longer time, further attempts at anchoring were given up and some more sections worked instead. The last stations N. of Fayal were taken on 26th June. On the way home to the English Channel the ALTAIR took 6 main stations (observations from surface to bottom) along the sectional line occupied by the ARMAUER HANSEN in May, while the latter ship repeated the whole section (43 stations) for the upper water-strata, the deepest observations being taken from 2800 metres. In this way the changes which

had taken place in the ocean between the Azores and the English Channel from May to July would be examined.

At the instigation of the Gulf Stream Committee, special investigations were made also in the north-eastern and western parts of the North Atlantic in the same season.

In October 1937 the Convener of the Committee had conferences with member of the Committee, Professor Martin Knudsen, and other colleagues in Copenhagen. The new research ship DANA was to go from Denmark to Iceland in the summer of 1938, and the suggestion was made that the DANA should go by way of the English Channel in order to work some sections W. and N. of the British Isles. It would give a valuable reconnaissance of regions that in parts were but little known. Dr. Å. Vedel Tåning, the leader of the DANA Expeditions, was in favour of the proposal, and it was adopted. Later on, a detailed programme was worked out, and the investigations were carried through from the 20th June to 6th July, under the charge of Mr. Helge Thomsen.

Through the courtesy of the Fishery Board for Scotland and Dr. Clark, Director of the Marine Laboratory, Aberdeen, the Scottish research ship EXPLORER was sent out to take some sections N. of the British Isles in co-operation with the DANA. A section was also worked in the Faeroe-Shetland Channel. The Scottish investigations were undertaken by Dr. Tait from the 14th June to 6th July.

At the suggestion of Dr. Tåning, Mr. Arni Fridriksson, Reykjavik, took part in the international co-operation and worked two sections in the Denmark Strait N.W. of Iceland. The observations were made on a cruise in the Icelandic Fishery Inspection ship THOR from the 26th June to 2nd July.

In the ATLANTIS, the research ship of Woods Hole Oceanographic Institution, a section was worked on the American side of the North Atlantic, from Montauk Point (Long Island) to Bermuda, between the 29th May and the 8th June. The greater part of the section was repeated 9th–17th July.

At the suggestion of Mr. Iselin, Mr. Floyd M. Soule in the Ice Patrol ship GENERAL GREENE (U.S. Coast Guard)

took a series of stations in the Gulf Stream area S. of the Newfoundland Banks.

The material of serial observations from the summer season of 1938 to be dealt with by the Gulf Stream Committee comprises:

ALTAIR (Germany) . . .	102	stations	with	1668	points	of	observations.
ARMAUER HANSEN (Norway)	171	,,	,,	2424	,,	,,	,,
ATLANTIS (U.S.A.) . .	45	,,	,,	598	,,	,,	,,
DANA (Denmark) . . .	78	,,	,,	1084	,,	,,	,,
EXPLORER (Scotland) . .	58	,,	,,	646	,,	,,	,,
GENERAL GREENE (U.S.A.) .	9	,,	,,	133	,,	,,	,,
THOR (Iceland) . . .	19	,,	,,	203	,,	,,	,,
Total .	482	stations	with	6756	points	of	observations.

The observations of temperature and salinity (88 series) at the anchor station of the ALTAIR are not included, nor the current measurements made.

In addition to the serial observations at the stations, more than 3000 observations of temperature and partly salinity were made by the ALTAIR, ARMAUER HANSEN and CARIMARÉ.

A large number of meteorological observations were made on board the research ships. Many radio-sonde ascents were successfully carried through from the ALTAIR.

Finally, it may be mentioned that the ALTAIR Expedition made numerous echo-soundings and thereby procured material for the construction of more detailed charts of the bottom topography than we have hitherto possessed from the areas in question. This is of importance in connection with the study of the local variations in the water masses.

The titrations of the water samples having been finished and the tables of observations prepared, a meeting of oceanographers in charge of the work at sea in the European ships was arranged at Bergen in April 1939. During a fortnight, Professor A. Defant, Professor B. Helland-Hansen, Dr. H. Mosby, Dr. J. B. Tait, Mr. Helge Thomsen and Professor G. Wüst jointly discussed the observations, and a great number of graphical representations were drafted. The results will be demonstrated at the General Assembly of the Association at Washington. The following statements may be made now:—

The vertical sections from the areas N. and N.W. of the Azores and W. of the British Isles reveal the existence of many very great local variations in the physical and dynamical conditions in the water masses. Horizontal charts can be constructed for the Azores sector, where 6 out of 7 nearly parallel sections were taken within a belt 120–130 nautical miles broad. The charts indicate a local division of the "Gulf Stream" into two or three parts between the western Azores islands and 44° N., with counter-currents in between. Some eddies appear, most conspicuously around the bottom elevation at 44°-45° N. and 33°–35° W. In some localities N. of the Azores, appreciable variations with time during a couple of weeks seem to have taken place. Variations with tidal periods and with the periodicity of inertia currents were observed in the upper water-layers at the anchor station. In the north-eastern area, where the DANA and EXPLORER operated, many more oceanographic observations were taken during about three weeks than in any single season before. The local variations along the sectional lines were so manifold that the course of isotherms and isohalines cannot be drawn satisfactorily in horizontal charts, the distance from one section to another being too great.

The variability in the physical and dynamical conditions seems to be just as prominent within the Gulf Stream area in the central and north-eastern parts of the North Atlantic as in the Norwegian Sea. The observations now made give a conception of oceanic conditions rather different from the view hitherto commonly held. The investigations add emphasis to the necessity for numerous stations in procuring an increased knowledge of current systems in areas like those examined. In many cases the local variations seem to be closely connected with variations in bottom topography, which—according to the well-known results of echo-soundings—has proved to be much more complicated than previously assumed.

As stated above, the investigations in 1938 were of a preliminary character, intended to enable the Committee to draw up a rational programme for the intended chief survey of the Gulf Stream area between America and Europe in a later year. It is to be hoped that the survey can be carried through

in the summer of 1941, and that many countries and ships will be able to join such an international co-operation. After the experiences now gained it seems evident that the programme should be based on the following general principles:—

1. A dense network of observations, not merely stations at short intervals along the sectional lines, but also short distances between the sections. The same sections ought to be worked twice at least during the time to be agreed upon for the co-operation.

2. The number of ships engaged in the survey being limited, relatively small areas only can be surveyed in one season. Two or three ships ought to co-operate in each area, working sections in belts of a reasonable length and width. The areas have to be selected according to their representative character as well as to the radius of action of ships engaged in the survey and the opportunity of calling at convenient harbours.

3. If possible, observations ought to be made at anchor stations in suitable localities within the areas selected.

The observations of temperature and salinity from the various ships engaged in the co-operation of 1938 will be published in the near future in an Appendix to the *Bulletin Hydrographique*, edited by the International Council for the Study of the Sea (Copenhagen). Preliminary reports on the investigations carried out by the ALTAIR and ARMAUER HANSEN Expeditions are in the hands of the printers, and are expected to be published before the Washington meeting of the Association takes place.

(The above Report was unanimously adopted at the General Assembly of the Association on 11th September 1939.)

Report of the Committee on Questions of Interaction between the Sea and the Atmosphere

Convener: H. U. Sverdrup (U.S.A.).
Members: C. O'D. Iselin (U.S.A.).
H. Mosby (Norway).
J. B. Tait (Great Britain).
G. Wüst (Germany).

Introductory Remarks

Instead of considering the entire question of the interaction between the sea and the atmosphere, which in its broadest aspects involves the whole problem of oceanic circulation and important phases of meteorology and oceanography, the committee will focus attention on the processes which take place within the contact zone between ocean and atmosphere.

When dealing with these processes, special consideration will be given to the problems of:

1. The stress which the wind exerts on the sea surface.
2. The evaporation from the sea.
3. The exchange of heat between the air and the sea.

The methods employed in dealing with these problems and the results obtained will be briefly reviewed.

1. The Stress of the Wind

Methods.—The methods for computing the stress of the wind can be divided into two classes: (A), those which require no knowledge of the wind profile near the surface, and (B), those which are based on such knowledge.

A. Computation of the stress of the wind regardless of character of wind profile near sea surface.

a. Stress derived from the piling-up effect of the wind (Windstau). The theory of this method was developed by

Ekman (1905) who first made use of it. The method has later been used by several authors. When applied to conditions in shallow water the method presupposes knowledge of the stress exerted on the bottom by the bottom current, and will, when such knowledge is lacking, give a maximum value of the stress of the wind. Numerical results are given below.

b. Stress derived from transport of air across isobars. The theory was presented and the method used by Rossby and Montgomery (1935) and by Sutcliffe (1936). When computing numerical values it is necessary to assume that the pressure gradient is nearly constant throughout the layer of frictional influence, and to know accurately the direction and velocity of the gradient wind. Numerical results are given below.

B. Computation of the stress of the wind based on knowledge of the wind profile.

a. Stress computed by means of the wind profile directly over the sea surface.

Application of Prandtl's theory (1932) for motion over a rough surface has been made by Rossby and Montgomery (1935), and application of von Karman's theory (1934) for motion over a smooth surface has been made by Rossby (1936). The former theory presupposes that the rough surface can be characterized by a roughness parameter, having the dimensions of a length, the latter theory assumes the existence of a laminar sub-boundary layer. The two theories lead to different wind profiles and to different values of the stress corresponding to a given wind velocity. It is, therefore, of the greatest importance to establish the actual velocity profiles. Results are discussed below.

b. Stress derived from angle between surface wind and gradient wind or from ratio of surface wind velocity to gradient wind velocity. The theory of this method was developed by Rossby (1936) by combining theories for the wind profiles in the lower and upper parts of the layers of frictional resistance. The validity of the theory depends on several assumptions and the application requires accurate determinations of the angle between surface wind and gradient wind or the ratio between the velocities. Results are discussed below.

Formulæ.—The formulæ for stress exerted by wind.

(1) $$\tau = \rho' \gamma^2 W^2$$

was proposed by G. I. Taylor (1915), on analogy with flow in pipes. Here τ is the stress, ρ' the density of the air, W the wind velocity, and γ a non-dimensional constant, whose numerical value depends upon the height above the ground at which the wind velocity is measured.

Prandtl's theory of the wind profile over a rough surface leads to the equation

(2) $$\tau = \rho' \frac{k_0^2}{\left(ln \frac{z + z_0}{z_0}\right)^2} W^2,$$

where $k_0 = 0{\cdot}38$ is von Karman's constant, z_0 is the roughness parameter of the surface, and z the height at which the wind velocity is measured. A comparison with the preceding formula gives

(3) $$\gamma = \frac{k_0}{ln \frac{z + z_0}{z_0}} = \frac{1}{W} \sqrt{\frac{\tau}{\rho'}}.$$

Von Karman's law for flow over smooth plates leads, on the other hand, to the equation for γ:

(4) $$\frac{1}{\gamma} + 5{\cdot}75 \log \frac{1}{\gamma} = 5{\cdot}5 + \log \frac{zW}{\nu},$$

where ν is the kinematic viscosity of the air.

Rossby's theory leads for a rough surface to a relation between z_0 (or γ, see (2)) and the angle between surface wind and gradient wind, and to a relation between z_0 (or γ) and the ratio between the velocities of the surface wind and the gradient wind.

Results of Determinations.—Table 1 contains a summary of results concerning the stress of the wind on the sea surface.

TABLE 1

Author	Method	$\gamma^2 10^3$	W m./sec.	z_0 cm.	Height of Wind Observation
Ekman (1905)	A a	2·6	20	..	?
Palmén and Laurila (1938)	A a	2·4	9–26	..	?
Rossby and Montgomery (1935)	A b	1·3	?	..	?
Sutcliffe (1936)	A b	0·4	7	..	10?
Rossby (1936)	B a	1·0–1·8	2–5	..	4
Rossby and Montgomery (1935)	B a	2·4	8	0·6	15
Rossby (1936)	B b	2·2	10–22	0·5	15
Rossby (1936)	B b	2·4	10–22	0·6	15

It appears that the formula (1) is valid at wind velocities above 6 to 8 m./sec. and that the coefficient γ^2 has the value ·0024 if the wind velocity is measured at a height of about 15 metres. This implies that at wind velocities above 6 to 8 m./sec. the sea surface is "rough" and characterized by a roughness parameter of 0·6 cm., as derived by Rossby and Montgomery from wind profiles observed by Wüst (1920) and Shoulejkin (1928). In this connection it should be emphasized that considerable weight should be given to the recent results by Palmén and Laurila, because these have been derived on a small number of assumptions.

At low wind velocities the available profiles indicate, as pointed out by Rossby, the existence of a laminar sub-layer, and the stress corresponding to a given wind velocity is therefore considerably smaller than would follow if the surface could be considered rough. Table 2 has been computed in order to demonstrate this difference.

TABLE 2.—VALUES OF TANGENTIAL STRESS OF WIND IN C.G.S. UNITS CORRESPONDING TO STATED WIND VELOCITIES AND ASSUMING THE EXISTENCE OF A LAMINAR SUB-LAYER, OR A "ROUGH" SURFACE CHARACTERIZED BY $z_0 = 0{\cdot}6$ CM.

	Wind Velocity, m./sec.								
	2	3	4	5	6	7	8	9	10
"Smooth" surface	0·04	0·09	0·16	0·24	0·34	(0·45)			
Rough ,,	(0·11)	(0·25)	(0·45)	(0·70)	(1·01)	1·38	1·81	2·28	2·83

Conclusions.—Table 2 brings out the fact that the stress corresponding to a given wind velocity is about three times greater over a rough surface ($z_0 = 0{\cdot}6$ cm.) than over a smooth surface. If the sea surface can be considered smooth at wind velocities below 6 to 8 m./sec. at 15 metres, it means that the effect of wind velocities below this limit are of no significance towards producing currents.

This result again leads to the important conclusion that it is highly desirable to obtain more observations of wind profiles over the sea at low and moderate wind velocity in order, if possible, to determine the relation between the profile and the velocity at a given level.

So far, it has been assumed that the temperature gradient in the air is nearly adiabatic because the above formulæ appear to be valid on this assumption only. Under stable or unstable conditions the wind profile will probably be changed and the above equations giving relationship between wind velocity and stress will no longer hold. A study of the wind profile under such conditions is therefore of great interest.

Suggestions.—Experience has shown that it is impossible to observe wind profiles from a ship because the hull and the rigging alter the profile. Even a small boat influences the important velocity near the surface. It must therefore be recommended to attempt such measurements from a float or, even better, from a submarine. A submarine would be particularly suited for such studies because room would be available for recording instruments of different types.

2. The Evaporation from the Sea

Discussion.—The evaporation from the sea has been mainly studied by means of measurements of evaporation from pans on board ships (Wüst's discussion of 1920 contains reference to earlier literature). The problem of evaporation can also be attacked as a problem of transport of water vapour by eddy conductivity (Sverdrup, 1936; Wüst, 1937; Sverdrup, 1938). We shall here consider the latter approach only.

In order to compute the transport of water vapour by eddy conductivity it is necessary to know both the variation of the vapour content with distance from the surface and the

value of the eddy conductivity. The former can be determined by direct observations at different levels, and the latter by observations of the wind profile, assuming the stress near the surface to be independent of height. Observations of the sea surface temperature must be included.

So far, very few series of measurements are available (Wüst, 1920, 1937; Montgomery's measurements in Sverdrup, 1938), but the results of these indicate that a formula may be derived by means of which the amount of evaporation can be computed from ordinary meteorological observations on board ship. It appears worth while to follow this matter up.

Suggestions.—The distribution of water vapour is also influenced by the hull and rigging of a vessel, and it is therefore not satisfactory to make observations of humidity profiles on board a large vessel. Such observations should, if possible, be conducted from a float or, even better, from a submarine. On board a submarine it will be possible to use instruments which cannot be used on a float and by means of which accurate data can be obtained. On a submarine it will be possible, for instance, to suck air in through pipes which reach to different levels above the surface and determine the humidity of such air by aspirated psychrometers, or to use Assmann psychrometers with reversing thermometers at different levels.

3. The Exchange of Heat between the Air and the Sea

Discussion.—This problem has been dealt with in a general way, but has received small attention as a problem of transport of heat by eddy conductivity. It appears, however, that the problem can be approached in a similar manner as the problem of evaporation, but for this purpose detailed knowledge of the temperature profile near the surface is needed. Very few observations of such temperature profiles are available (Wüst, 1920, 1937), and it is therefore highly desirable to obtain more data.

Suggestions.—The distribution of temperature is probably even more disturbed by the hull and rigging of a vessel than is the distribution of water vapour. It is therefore again recom-

mended to undertake such observations from a float or, even better, from a submarine, on board which more satisfactory instruments could be housed.

Instruments

The committee does not wish to recommend any special type of instruments because the type of instrument will depend greatly upon the conditions under which the observations are to be carried out and may, in each single case, have to be adapted to the circumstances. Assmann psychrometers with reversing thermometers deserve consideration.

A memorandum from Dr. A. F. Spilhaus dealing with suggested instrumental equipment for the study of wind, temperature, and humidity gradients is attached as an appendix to this report.

General Recommendations

In view of the importance to oceanography and meteorology of the studies of the stress of the wind, the evaporation from the sea, and the exchange of heat, in view of the fact that these problems can be studied by means of detailed observations of wind, humidity and temperature profiles directly over the sea surface, and in view of the fact that such profiles can best be observed from a submarine, the committee wishes to express the hope that through co-operation with the Navy of its own country one or more institutions may obtain facilities for conducting these studies.

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Appendix to Report of Committee on Questions of Interaction between the Sea and the Atmosphere

Memorandum on Suggested Instrumental Equipment for the Study of Wind, Temperature, and Humidity Gradients in connection with Questions of the Interaction between the Sea and the Atmosphere.

By

A. F. SPILHAUS

New York University, Woods Hole Oceanographic Institution

In view of the fact that profiles of all measured quantities are required, at least four suitably distributed points in the vertical are desirable. In considering instrumental equipment for the above purpose, it immediately appears that, as the principal problem involved is the measurement of gradients, the actual difference between the measured quantities (velocity, temperature, or humidity) at two of the levels is required, and this difference will be quite small. It, therefore, would seem that it is desirable to devise instrumental equipment which would intrinsically measure the difference directly rather than to rely on the measurement of the actual quantities.* Such difference methods are not immediately available, and if they cannot be used it is of the utmost importance that sufficient accuracy in the measurement of the absolute values be maintained, that when differences are taken the result will still be within satisfactory limits.

The committee has, in its general recommendations, suggested that, through Naval co-operation, a submarine would

* Absolute value must, of course, be measured at least at one point.

be the best base for such measurements. From the instrumental point of view this is unquestionably the case, as comparatively delicate recorders can then be included in the system. If, however, it is necessary, in preliminary work, to utilize a float, the instruments will have to be of a rather different character. Another alternative as to the base of operations, which considerably simplifies the instrumental problem, is that of utilizing a low sand spit with a maritime exposure in such a direction that winds blowing from unobstructed ocean regions may reach the spit unimpeded. Then, measurements made right at the edge of the sand would essentially be as satisfactory as those made from a float at sea. Furthermore, the utilization of a solid base of operations would enable a permanent mast to be set up, which would not roll or pitch, and, therefore, the velocity determinations would not be affected by such movement.

In the present memorandum, suggestions for both the submarine and the float as bases will be made, and it is evident that such suggestions can be applied directly for use on a sand spit as is proposed above. The methods available may be classed in the following fashion:—

(1) Non-recording measuring devices requiring frequent observation. The element and indicator would be *in situ* at the particular elevation where the observation is to be taken.

(2) Recording devices requiring only infrequent attention. Element and recorder *in situ* at the elevation where the observation is to be taken.

(3) Remote indicating devices. Indications being received at some distance from the mast. (Requiring frequent observation but without disturbing the mast or instruments on it.)

(4) Remote recording devices where a complete recording is made at a convenient location away from the mast. (Observation unnecessary.)

In general, methods (1) and (2) would only be in an extremely simplified arrangement such as might be used for a preliminary study from a float; while (3) and (4) would be suitable for use on a submarine. Each of the four systems has its particular advantages and disadvantages, and these will be

summarized here with a view to the subsequent choice of equipment:

Wind.—The alternatives for the measurement of wind velocity at various levels are:

(*a*) Cup anemometers.

(*b*) Pressure tube anemometers.

(*c*) Electrical methods (hot wire anemometers, etc.).

The electrical methods may be ruled out immediately as not practicable in the present investigation. Between the cup anemometer and the pressure tube anemometer the choice lies in considerations of simplicity, on which score a cup anemometer, dial reading or recording, will probably prove most satisfactory in all methods (1) to (4).

Temperature.—For the measurement of temperature gradients, the possibilities are:

(*a*) Mercurial thermometers.

(*b*) Mechanical recording thermometers (Bourdon tube or bi-metal).

(*c*) Electrical methods (resistance thermometer, etc.).

In this case, the mechanical recording thermometers may be eliminated from consideration as these types of instruments do not, in general, have the requisite accuracy and need frequent re-calibration.

Between the use of mercurial thermometers and electrical methods, it may be definitely stated that it is simpler to obtain a mercurial thermometer with the required accuracy, although, of course, resistance thermometers can be obtained which would be suitable. The mercurial thermometer in addition has the great advantage of comparative inexpensiveness, but this is coupled with the disadvantage that it is not possible to make it record by any simple method (other than photographically). If, therefore, a mercurial thermometer is to be used, it will be necessary for it to be of the reversing type, so it will hold its indication while being taken down from the particular elevation on the mast in order to make a reading. The resistance thermometers have the advantage of remote indication and the possibility of remote recording, and have, in addition, the possibility that a direct "difference" circuit may be used, so that differences between temperatures at two heights may be

measured directly. The choice, therefore, between these two instrumental methods for the measurement of temperature lies in the choice of the general method for the complete investigation, *i.e.* whether it is required to have remote indications or whether it is satisfactory to provide frequent observation.

Humidity.—The existing instruments for the measurement of humidity are:

(*a*) The hair hygrometer.
(*b*) The aspiration psychrometer (wet and dry bulb).
(*c*) The dew point method.
(*d*) Chemical absorption methods.

Here, the chemical absorption methods may be eliminated as impractical for obvious reasons. Furthermore, the hair hygrometer, while in common use in general meteorological practice, is well known to require the greatest care and recalibration of the hair elements if great accuracy is demanded. Both the measurement by dew point or the use of aspirated psychrometers are practical and may be highly accurate methods of determination. The aspirated psychrometer, however, has the advantages that existing standard equipment is available for the arrangement, while the use of a dew point method would entail more careful technique of measurement.

Remote reading or recording wet bulb thermometers (such as wet bulb resistance thermometers) are not recommended, because of the continual care which must be given to the wicks and wetting devices if accuracy is to be insured, nor are such reading and recording methods necessary in the case of humidity measurements, for here the air can be brought down in tubes from the test points to the locality where it is convenient to make measurements, without change in its water vapour content. Furthermore, an additional simplification of method is obtained if the air from the several points of observation is brought down and caused to pass through coils in the same water-bath such that all may acquire the same dry bulb temperature. If this is done, it is no longer necessary to know the dry bulb temperature for the determination of the vapour content gradients, as these gradients are dependent on the wet bulb temperatures alone.

Suggestions for Complete Equipment.—In view of the foregoing analysis of the methods available, two systems of instrumental equipment for the complete measurements are suggested. While any combination of the instrumental methods suggested may be utilized, it is thought here that it would be best merely to indicate two of the best combinations:

(*a*) The simplest method employing non-recording devices.

(*b*) A simple remote indicating method which might be used on a submarine.

For (*a*), mercurial thermometers are used in reversing Assman psychrometers, see fig. 1. On each reversing frame is mounted a small dial-reading cup anemometer. Each unit is so equipped that the anemometer may be started after being hauled into place on the mast, thus all the anemometers are started simultaneously and are allowed to run for a five-minute period while the psychrometers are attaining equilibrium. At the end of this period, a further tripping device is arranged such that all psychrometers are reversed together. Simultaneously the anemometers are disengaged such that the dial reading at the end of the period may be determined after lowering the instruments.

The instruments are then lowered to the base of the mast, the readings completed, the wicks examined and re-wetted, and are hauled up again and the procedure repeated.

With this extremely simple equipment, it is believed that highly accurate observations, fairly frequently made, would give some useful data.*

The second and more elaborate system, such as is suggested for use on a submarine, is the combination of cup anemometers for wind velocity, resistance thermometers for air temperature, and tubes communicating to remote psychrometers for humidity measurements. This system is indicated in fig. 2. The cup anemometers may be very easily arranged such that they are remote, recording electrically by a simple contact mechanism. The resistance thermometers may be arranged to be remote,

* In a preliminary investigation which it is proposed to carry out at Woods Hole Oceanographic Institution during this summer, this is the method which will be tried, whether the system is situated on a float or at a sand bar.

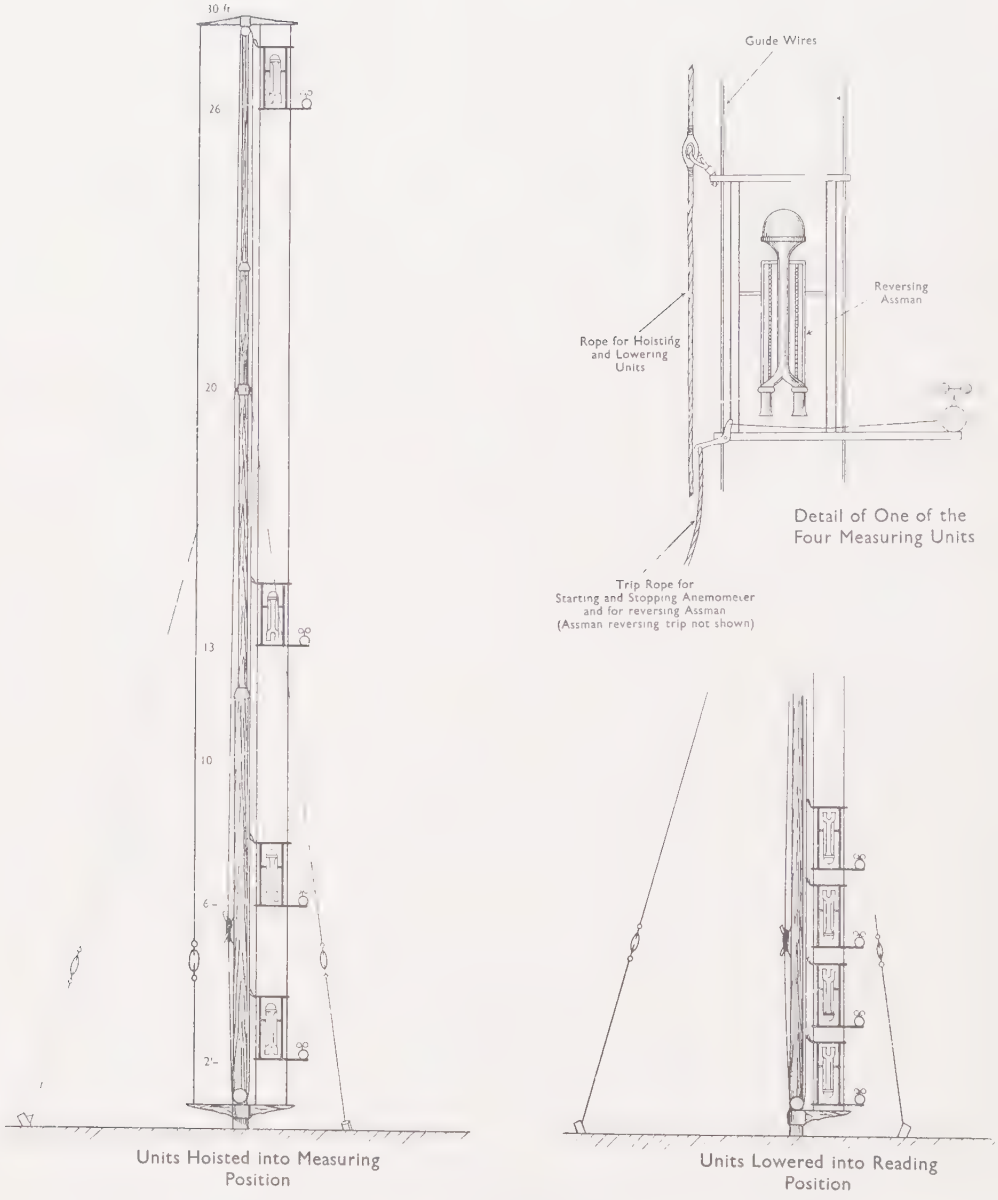

FIG. 1.—General Scheme of proposed Equipment for the Measurement of Wind, Temperature, and Humidity Profiles.

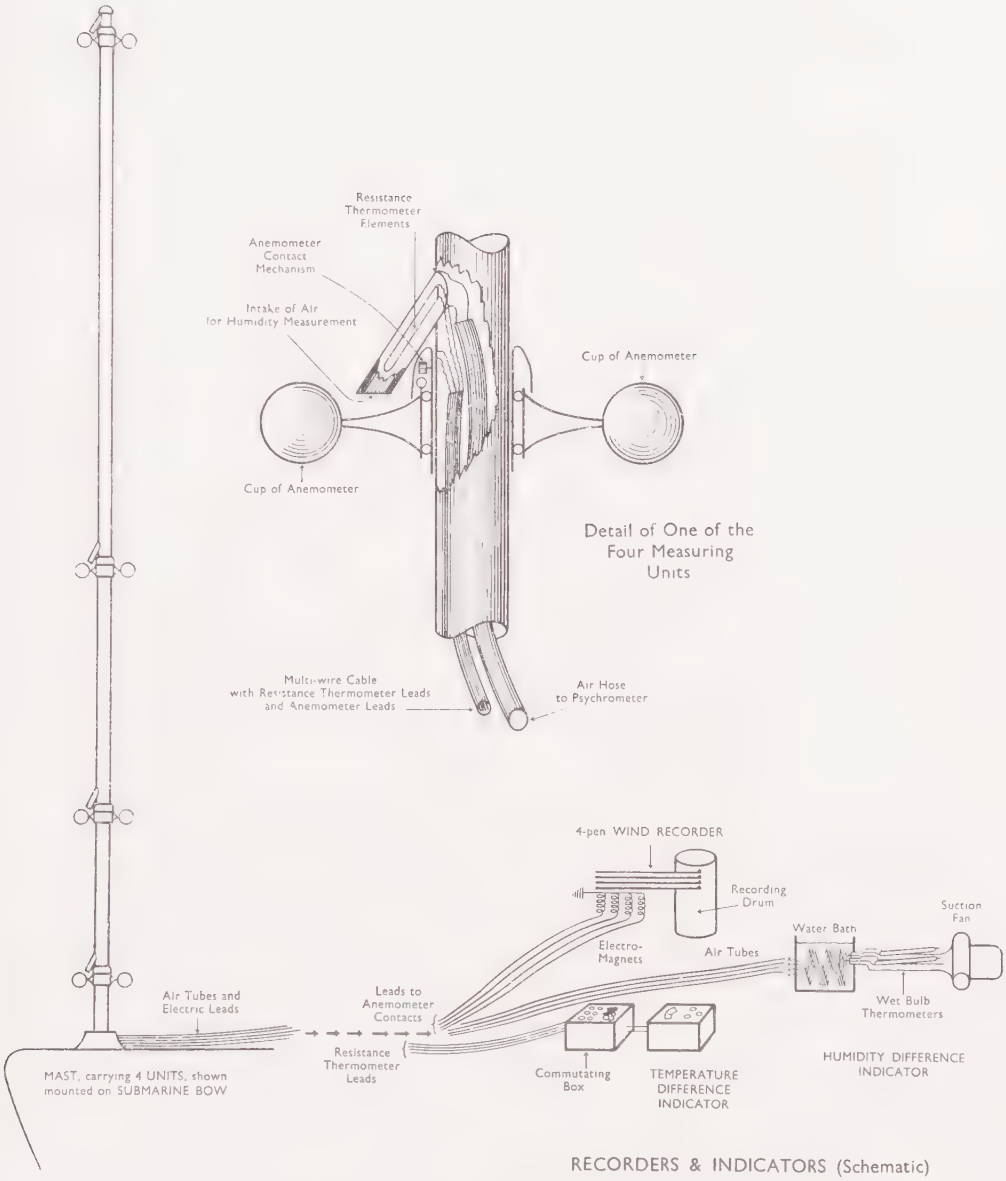

FIG. 2.—General Scheme of proposed Equipment (Remote Recording and Indicating) for the Measurement of Wind, Temperature, and Humidity Profiles.

indicating on a direct difference circuit,* and the tubes which draw the air down for humidity measurements would all pass through a water-bath such as is described above, and thence to four wet-bulb thermometers for measuring the vapour content gradients. Each unit on the mast with which the submarine would be equipped is identical, and its position on the mast can be varied according to the particular distribution of points required.

While in the foregoing an attempt has been made to indicate practical systems of instrumental equipment for the proposed investigations, it is not the intention of the writer to suggest that these combinations are the only ones or are even the best ones for the purpose. It is his belief, however, that they do perhaps exhibit features which will enable them to be arranged most simply and still maintain the requisite accuracy.

(The above Report was unanimously adopted by the Joint Meeting of the Associations of Physical Oceanography and Meteorology on 13th September 1939.)

* The details of the arrangement of the resistance thermometers and the "difference" circuit have been worked out by Messrs. Leeds & Northrup Company in Philadelphia.

Abstracts of Communications

F 1

Antrag

Von

G. BÖHNECKE

Berlin

1. Der Antrag lautet:

Es wird eine intensive Erforschung der vertikalen und horizontalen Wasserbewegungen eines Randmeeres (z.B. der Nordsee), hervorgerufen durch Gezeiten, Wind und Luftdruck, vorgeschlagen.

2. Zweck des Antrages:

Die Gesetze, die den Ablauf der Gezeitenerscheinungen beherrschen, besitzen allgemeine Gültigkeit für alle Meere; nur die Erscheinungsformen sind Änderungen unterworfen. Werden in einem Meere ausgedehnte Beobachtungen des Wasserstands und des Stroms durchgeführt, so lassen sich die grundlegenden Zusammenhänge zwischen den Gezeitenerscheinungen in senkrechter und waagerechter Richtung ermitteln und der Grad der Übereinstimmung mit der Theorie prüfen; dadurch würde das Ergebnis für alle gezeitenkundlichen Untersuchungen auch anderer Meere von hervorragender Bedeutung.

3. Kreis der an der Durchführung Beteiligten:

Je nach dem auszuwählenden Meer, das am besten möglichst abgeschlossen wäre, würden die Anliegerstaaten bereits durch Aufstellung von Küstenpegeln usw. stark beteiligt sein. Für die Beobachtungen auf See wäre es wünschenswert, vielleicht sogar erforderlich, daß sich möglichst viele Staaten mit Fahrzeugen und Instrumenten beteiligen würden.

4. Durchführung der Beobachtungen im Einzelnen:

Grundsätzlich müssen alle Beobachtungen gleichzeitig

ausgeführt werden; erstrebenswert ist ein Beobachtungszeitraum von 15 Tagen.

An Beobachtungen würden vorzusehen sein:

(*a*) Wasserstands-; (*b*) Strom-; (*c*) Salzgehalts-; (*d*) Temperatur-; und (*e*) meteorologische Beobachtungen, außerdem wären Lotungen und Seegangsmessungen nützlich.

5. Aufbereitung und Verarbeitung der Ergebnisse der Vermessungen:

Das Material wird zweckmäßig einer zentralen Stelle übermittelt und von dieser nach einheitlichen Gesichtspunkten aufbereitet und nach Fertigstellung den beteiligten Staaten zur Verfügung gestellt. Die wissenschaftliche Ausarbeitung würde auf Vorschlag der zentralen Stelle den entsprechenden Fachwissenschaftlern der beteiligten Staaten übertragen werden können.

F 2

Antrag

Von

A. SCHUMACHER

Hamburg

Über die Abmessungen der Meereswellen, die in den verschiedenen Meeresgebieten auftreten (als ungefähre Norm und als Ausnahmefälle) ist noch so gut wie nichts statistisch festgelegt, obwohl in nautischen Kreisen der verschiedene Charakter des Seegangs in verschiedenen Meeren, z.T. sogar in verschiedenen Bereichen des offenen Ozeans, qualitativ durchaus bekannt ist. (z.B. Unterschiede auf der Route über den offenen Ozean zwischen dem Englischen Kanal und New York.) Ein umfangreiches statistisches Material, das nur durch internationale Zusammenarbeit zu beschaffen ist, wird wahrscheinlich für bestimmte Meeresgebiete charakteristische Unterschiede hinsichtlich der vorherrschenden Wellenabmessungen und des vorherrschenden Verhältnisses von Länge und Höhe erkennen lassen, die z.B. in den Tiefenverhältnissen (bei Randmeeren) und in den meteorologischen Verhältnissen (in Verbindung mit den jeweils möglichen "Windbahnen") ihre Ursache haben. Neben dem rein wissenschaftlichen Interesse liegt die große technische Bedeutung einer solchen wirklich verläßlichen Materialsammlung auf der Hand.

Für die Gewinnung dieser Beobachtungen müßten geeignete Schiffsoffiziere geschult werden, die möglichst unter Verwendung besonderer Formulare sorgfältige fortlaufende Angaben über Höhe, Länge und Periode des Seegangs einsenden würden. (Diese Angaben wären also vornehmlich durch Vergleich mit den Schiffsabmessungen zu gewinnen.)

Außerden ist auf die Bedeutung exakter Messungen hinzuweisen. Von Forschungsschiffen und von Feuerschiffen aus kann das Seegangsmeßgerät der Deutschen Versuchsanstalt für Luftfahrt (nach W. Pabst) verwendet werden, von in Fahrt befindlichen Schiffen die stereophotogrammetrische Methode.

F 3

Vorschlag des Instituts für Meereskunde, Berlin, betreffs einer Fortführung der "Grundkarte der ozeanischen Lotungen des Atlantischen Ozeans" und Ausdehnung dieser Arbeit auch auf die anderen Ozeane

Von

A. DEFANT

Als Ergänzung zu der im "Meteor"-Werk erschienenen Übersichtskarte der Tiefenverhältnisse des Atlantischen Ozeans hat sich die Herausgabe einer Quellenkarte aller vorhandenen Lotungen als notwendig erwiesen. Diese Karte, von der Anfang 1939 2 Blätter von 14 des ganzen Atlantischen Ozeans gedruckt vorlagen, verfolgt folgenden Zweck:

1. Eine quellenmässige Erfassung möglichst *aller* vorhandenen Tiefseelotungen;
2. Eine kritische Sichtung und Ausmerzung ungenauer oder fehlerhafter Angaben der Tiefe oder der geographischen Koordinaten;
3. Einwandfreie kartographische Darstellung der Lotzahlen, Verschlüsselung des Lotschiffes, Unterscheidung der Lotungsart u.a.
4. Keine Isobathenführung in der Karte, sondern unter Berücksichtigung ihrer Unsicherheit auf Deckblättern.

Die Tatsache kann kaum geleugnet werden, dass Planlegung, Ausführung und Stil dieses Kartenwerkes einem Bedürfnis in der Ozeanographie entgegenkommt, ja, dass auch die anderen Zweige der Geophysik, die Geologie und Geotektonik an dieser flächentreuen Karte stark interessiert sind.

Bei der Durchführung der Aufgabe hat sich ein technischer

Apparat ergeben, der in erster Linie aus einer Kartothek, aus zahlreichen grossmaßstäbigen handschriftlichen Arbeitskarten und Sonderkarten u.a. besteht. Diese Dinge lassen sich im Bedarfsfalle jederzeit durch neuanfallendes Material ergänzen und auf dem Laufenden halten.

Mit Abschluss des "Meteor"-Werkes würde die Fortführung dieses Kartenwerkes aufhören, da keine Mittel vorhanden sind, um die erschienenen Blätter im laufenden zu halten und ständig zu berichtigen. Ausserdem ist von verschiedenen Seiten der Wunsch laut geworden, diese Arbeit mit gleichem Stil, gleicher Projektion und gleichem Maßstab auch auf die übrigen Ozeane auszudehnen. Diese Aufgabe, für die im Institut für Meereskunde an der Universität Berlin der Grundstock geschaffen und reiche Erfahrungen gesammelt sind, übersteigt zur Zeit seine personellen und materiellen Kräfte. Durchführbar wäre sie, wenn neben dem Bearbeiter als wissenschaftlichen Leiter

1. eine wissenschaftliche Hilfskraft,
2. ein voll ausgebildeter, qualifizierter technischer Kartograph (mit einer gelegentlichen kartographischen Hilfskraft),
3. eine Bürohilfe

bereitgestellt würden. Dieser verhältnismässig kleine Apparat wäre imstande, in absehbarer Zeit für alle Ozeane dieses Kartenwerk in gleichmässiger Bearbeitung durchzuführen.

Eine Inventur der sich ständig häufenden Echolotzahlen, deren listenmässige Publikation schon nicht mehr technisch durchführbar ist, wird unbedingt nötig. Eine solche Bestandsaufnahme kann, wenn eine wirkliche kritische Sichtung nach einheitlichen Gesichtspunkten durchgeführt werden soll, nur *einer einzigen erfahrenen Stelle* übertragen werden, die das Material und die Ergebnisse ihrer Arbeit jederzeit allen Interessenten zugänglich machen müsste.

C I 1

Über neuzeitliche Geräte für Wasserstands- und Strommessungen sowie mit ihnen gewonnene Ergebnisse

Von

W. HANSEN

Marineobservatorium, Wilhelmshaven

Die Erforschung der Bewegungsvorgänge im Meer gehört zu den wesentlichsten Aufgaben der Ozeanographie. Die bedeutendsten Ursachen haben diese in den gezeitenerzeugenden Kräften, in der tangentiellen Schubkraft des Windes und in den Dichteunterschieden des Meerwassers. Die Bewegungsvorgänge in vertikaler Richtung werden als Wasserstandsänderungen, die in horizontaler Richtung als Ströme wahrgenommen.

Die Geräte zur Messung des Wasserstandes haben eine ihrer Verwendung als Küsten- oder Hochseepegel angepaßte Bauart. Besonderes Interesse beanspruchen die Hochseepegel. Das Prinzip der Wasserstandsmessung beruht auf der Bestimmung des Druckes der über dem Pegel befindlichen Wassersäule. In den modernen Geräten wird die Volumänderung einer konstanten Luftmenge photographisch gemessen und der Druck oder die Höhe der Wassersäule auf Grund der Gasgesetze ermittelt.

Die Geräte für Strommessungen benutzen die verschiedensten Prinzipien zur Bestimmung der Geschwindigkeit und der Richtung der Wasserbewegung. Für Geschwindigkeitsbestimmungen werden u.a. benutzt Flügel, Schaufelräder, Schrauben und Schalen. Die Richtungsbestimmung erfolgt im allgemeinen mit Hilfe eines Kompasses oder durch Aufhängung des Gerätes in einem Rahmen, der der Schiffslängsachse parallel ist.

Aus der großen Zahl der Geräte seien nur die Hochseepegel von Rauschelbach und Graafen, die bis 350 m Tiefe verwendet werden können, die Strommesser von Böhnecke und Rauschelbach, mit denen vom Fahrzeug aus beobachtet wird, und der Schaufelradstrommesser, der auf See verankert wird, genannt. Die Bauart und die Handhabung werden auf Lichtbildern gezeigt.

Strom, Wasserstand, Temperatur, Salzgehalt und Dichte des Wassers stehen in inniger Beziehung zueinander, deshalb müssen diese Elemente möglichst gleichzeitig an einer Stelle gemessen werden. Aus den zeichnerischen Darstellungen aller oder eines Teiles der genannten ozeanographischen Elemente läßt sich bereits ein Überblick über die Zusammenhänge zwischen diesen Größen erhalten. Das Endziel bleibt aber immer die wissenschaftliche Bearbeitung des Beobachtungsmaterials, d.h. das Herausarbeiten der Gesetzmäßigkeiten, nach denen die Bewegungsvorgänge vor sich gehen.

Aus der großen Zahl der Aufgaben, die die Bewegungsvorgänge im Meere behandeln, seien nur die folgenden genannt: Die Wasserstandsänderungen und die Gezeitenströme von der Oberfläche bis zum Boden. Die Abhängigkeit der Wassergeschwindigkeit und des Wasserstandes vom Wind. Der Einfluß der Wasserbewegung auf die vertikale Temperatur-, Salzgehalt- und Dichteverteilung.

Zur Behandlung dieser Aufgaben reichen die Beobachtungen einer ozeanographischen Station aus (Beispiel: Ankerstationen auf der Echobank und bei den Kapverden). Die Erforschung der Bewegungsvorgänge in einem gesamten Meere oder Ozean läßt sich dagegen nur durchführen, wenn an möglichst vielen Punkten der freien See und der Küste Beobachtungen gesammelt und diese unter Benutzung der theoretischen Erkenntnisse verarbeitet werden.

GI 2

Some Experiments with the Marégraphe Plongeur Favé

By

A. T. DOODSON

Liverpool Observatory and Tidal Institute

Three instruments have been used at depths of 25 fathoms. The object in view was to get exact values of the pressure gradient over a distance of six miles, in connection with experiments on turbulence. Extreme accuracy was desired and experiments have been made on the characteristics of the calibration curves, both by use of a specially designed mercury manometer and by the use of a tide-well. The conclusions may be summarised as follows:—

(1) The gauge is compact and well designed and requires alterations only in details.

(2) It is fairly easily handled.

(3) There is a very high nominal accuracy in the readings of the curves.

(4) The smoked-glass plates are not difficult to prepare, but there is room for improvement in the technique.

(5) The attachment of the needles to the Bourdon tubes needs to be redesigned, for it is very troublesome to insert the needles in the clutches, and the light flat springs are too flexible.

(6) The steel spiral springs on the valves outside the tanks are very unsatisfactory, and they should be replaced by strong helical springs, preferably of phosphor-bronze.

(7) The tanks should be made capable of rapid immersion, as at present they float too long before immersion.

G I 3

Measurements of Ocean Currents on board the "Armauer Hansen" in 1930

By

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With the main object of studying the dynamical character of an ocean current, Dr. B. Helland-Hansen and the writer made in 1930 an expedition to the trade-wind region between Portugal and the Canaries. Since 1923 we had made preliminary technical experiments, and the small research ship *Armauer Hansen*, belonging to the Geophysical Institute of Bergen, was equipped with some gear specially designed for the purpose. Much care was particularly bestowed on the invention of satisfactory appliances for anchoring.

The observations were concentrated on six anchor stations, over bottom depths between 1900 and 3970 metres, and were continued for something between 49 and 141 hours at the several stations. At each station measurements were made (as a rule with three instruments simultaneously) alternating at six or seven levels from 5 to 1000 metres below the surface and with the shortest possible intervals of time.

From a technical point of view the results confirmed the experience of the "Meteor" expedition, that trustworthy current-measurements can, under favourable conditions, be made even in the deep ocean, and they indicated particularly that the swayings of the ship round its anchor have not as a rule materially affected the results. These conclusions were further supported by an analysis of the variations of the ship's bearing. On the other hand, the movements of the water itself were found to be subject to rapid, irregular variations, owing to which it would have been impossible to examine

satisfactorily the mean motion by means of single measurements only.

On one occasion the measurements were continued for 64 hours, and arranged with the special view of verifying the theoretical structure of a drift-current; and with a little good-will the verification can be considered as successful.

Semidiurnal, clockwise rotating tidal currents were very marked. They showed, however, differences of amplitude as well as of phase from level to level, thus indicating the existence of semidiurnal internal waves of apparently a rather confusing character. Very marked diurnal components of velocity occurred as well, but it is doubted whether they were of tidal character. There are reasons for regarding them as inertial currents with a period of 12 pendulum-hours, which, on the latitude of 30°, is very nearly equal to 24 hours.

The measurements at the longest station showed, in addition, other apparently periodical variations of velocity with still larger periods. Their periodical character must, however, be regarded as questionable, because they cannot be understood dynamically. Non-periodical, irregular variations of velocity, suggesting passing eddies, have been studied and show an obvious influence of the earth's rotation.

After elimination of all such periodical and non-periodical transient variations, "mean values" of the velocity components were calculated. These mean values also varied considerably with time, so that it was not possible from a series of observations, extending over as much as six days, to calculate average velocity components which could be relied upon as even approximately representative from a geographical point of view.

GI 4

A New Electrically Recording Current-Meter

By

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Experimental measurements of turbulence required a meter of high sensitivity, capable of yielding direct readings at frequent intervals of time. The apparatus had to be compact and light enough to be easily handled from a small ship, without elaborate equipment.

The direct readings of velocity are obtained from a pressure plate in the shape of a propeller, so as to give rotatory motion to the arm of a potentiometer. The scale of the instrument with the pressure wheel normally in use is from 0 to 4 knots, but a larger pressure wheel gives from 0 to 1·5 knots. The instrument is sensitive to 0·05 knot with the normal wheel, and by a special spring control of the pressure wheel the readings are practically linear with the velocity of current, whereas most other meters give readings proportional to the square of the velocity, and are somewhat insensitive to low speeds.

The magnet frame normally swings freely, but at intervals of 15 sec. or 30 sec. it can be depressed to make contact with a potentiometer ring. The depression is effected by electro-magnets operated by a clock in the ship.

The meter hangs at the end of a 4-core cable protected by a woven mesh-work of phosphor bronze wire. The meter weighs less than 100 lb., and the breaking strain of the cable is over 500 lb. A friction band on the drum is a safeguard against undue strain on the cable.

A direct reading indicator can be used as an alternative to the recorder, which gives records of the shadows of the needles of the two galvanometers in the direction and velocity electrical circuits.

GI 5

Current Measurements near the Sea Bottom

ABSTRACT

By

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An apparatus is described for carrying out measurements of ocean bottom currents and for determining the character of the vertical current velocity profile near the sea-floor. Through the use of this instrument it has been possible to measure current velocities within a meter of the bottom, from an unanchored vessel in the open sea, at depths as great as a thousand meters.*

The maximum observed velocities near the bottom in relatively deep water were of the same order of magnitude as that of most surface currents in the open ocean, but the currents were found to be constantly shifting in both speed and direction. Intervals in which the velocity was less than 2 or 3 cm./sec. were occasionally followed by some of the highest measured velocities. The observed irregular movements of the bottom water probably can be best interpreted as indicating the presence of moving eddies with vertical axes, perhaps analogous, though on a smaller scale, to the non-stationary slope currents arising from fluctuations in the wind system, described by Rossby.†

Nearly simultaneous measurements of velocity at three heights between 20 and 130 cm. above the bottom in shallow

* F. P. Shepard, R. Revelle, and R. S. Dietz: "Ocean Bottom Currents off the California Coast," Science, vol. 89, pp. 488–489, 1939.

† C. G. Rossby: "On the Mutual Adjustment of Pressure and Velocity Distributions in certain Simple Current Systems—II," Jour. Marine Research, Vol. 1, No. 3, pp. 239–262, 1938.

water * showed the existence of steep velocity gradients, although marked individual fluctuations characteristic of turbulent motion were observed. Average velocity profiles indicated that there was no laminar sub-boundary layer immediately above the bottom, but that on the contrary the bottom could be regarded as a rough surface. The average velocity varies logarithmically with height above the sea floor according to the well-known equation

$$V_z = \frac{W}{0{\cdot}165} \log \left(\frac{z + z_0}{z_0} \right),$$

where V_z is the velocity at the height z above the bottom, W is a constant, called the "friction velocity," and z_0 is a "roughness" parameter having the dimensions of length. In the shallow tidal channels investigated z_0 varied between 2 and 8 cm. Since the observed velocity profiles were logarithmic, the shearing stress at the bottom may be calculated on the basis of von Karman's law for flow over a rough surface, and if the assumption is made that this shearing stress was constant in intensity and direction within the bottom water layer the eddy viscosity at various heights above the bottom may be determined. The shearing stress calculated for the conditions of observation varied between 2 and 54 dyne/cm.^{2}, while the coefficient of eddy viscosity at one meter above the bottom ranged between 60 and 300 gm./cm./sec.

* R. H. Fleming and R. Revelle: "Current Velocity Profiles near the Sea Bottom." To be submitted to the Journal of Marine Research.

GI 6

Instruments, Methods, and certain Results relating to a scheme of Continuous Current Observing in the North Sea and English Channel

By

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The fishery researcher working in the area named must take up an entirely practical and non-academic attitude to the business of investigating currents. His concern is with an area where tidal streams hold sway. Sometimes the flood stream predominates, and sometimes there is an excess run of the ebb. In response to changing wind conditions which play an all-important rôle, these two situations can alternate with each other from day to day. It would seem impossible to attach much real value to any scheme of investigations which took account of a brief period only. No matter how ambitiously planned and efficiently carried out, results whose potential utility was commensurate with their scientific interest could hardly be forthcoming.

When planning researches on water movements it is worth while deciding first where one's chief interests lie. If they relate to the fortunes of fish eggs and larvæ borne along by the stream, one is not necessarily greatly interested in the bulk of water in movement to and fro. The man who is interested in the maintenance of coasts most assuredly is; depth of water and silt burden are prime concerns to him. Volume transport may also matter greatly to the investigator who will make inferences concerning currents from attention paid to the distribution of the usually studied elements. On severely practical grounds involving proper consideration of cost and possible duration of working, we are forced to make all the use

we can of lightships. It happens that we can observe the water movements past them continuously throughout the whole year, no matter how wild the weather or silty the water. Also, no difficulty arises when shallow observations are wanted from steel ships. A description of the instrument used is given in the booklet circulated, and reprints provided present specimen results obtained. Ordinary simple surface floating drift-bottles are little used by the Lowestoft Laboratory for a variety of reasons, but considerable use is made of a composite bottle system which rides a fathom deep in the water. This system, figured in the leaflet distributed, floats for a time only and then drops a questionnaire bottle to the sea-floor, there to await capture in a ground fishing net. They are used monthly off the Yorkshire coast, and specimen results are exhibited. Wind can rule their movements, and so much importance is ascribed to the rôle played by wind over the area as a whole, that designs have been worked out for a totalising anemometer from which it will be possible to read directly how many miles of wind have blown from different quarters over a period. It is also intended to bring into use for studying the water movements in coastal areas of special interest, a newly designed self-anchoring, self-signalling, and self-timing drifting buoy, able to work without regard to weather conditions. The apparatus in question is described in a pamphlet circulated.

With the chief piece of apparatus used—the Vertical Log Current-Meter—non-stop observations were carried out from ten lightships all through this last winter (1938–39).

G II 2

General Remarks on Turbulence in the Atmosphere and the Ocean

By

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Turbulence can, in the broadest sense, be defined as a system of irregular and random motions which is superimposed upon a simple pattern of flow. Using this definition one will have to deal with different types of turbulence, depending upon the dimensions of the pattern of flow under consideration.

The field of turbulence is so wide that, for the purpose of the following discussion, it appears desirable to focus the attention on a few problems only. As such have been selected, first, the question of turbulence of the air directly over the sea surface, because knowledge of this phenomenon is of the greatest interest both to maritime meteorology and to oceanography. When dealing with this question abstracts are presented of the report from the Committee on Questions of Interaction between the Sea and the Atmosphere. Second, the question has been selected of lateral turbulence in the atmosphere and the ocean, because this phenomenon has in recent years received considerable attention and has given rise to interesting speculations and theoretical considerations, which will be presented by Professor Rossby.

G II 3

An Attempt to Measure the Frictional Forces in a Tideway

By

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The dynamical equations for the tidal motion of the water, at a particular depth at a particular station, involve the accelerations, the horizontal pressure-gradients, and the forces of internal friction. The accelerations can be calculated from observations of the currents, and the variable parts of the horizontal pressure-gradients can be calculated from observations of the variable parts of the pressure at the sea-bottom at three stations. Hence the forces of internal friction can be calculated.

The necessary observations have been carried out in a small region of the Irish Sea to the south of the Isle of Man, about five sea-miles from the coast, where the depth of water is 50 metres. For the very difficult operation of measuring the pressure-gradients, the *marégraphe plongeur* Favé was used. The calculations have also been carried out, in so far as they refer to the principal harmonic constituent of the tides M_2.

It appears that the resultant forces of friction on vertical columns of water between the free surface and different depths are approximately proportional to these depths, and that the directions of these forces are approximately the same as those of the currents. If the friction had been due principally to the effect of the sea-bottom, we should have expected the directions to be opposite. It therefore appears that, at the station considered, the frictional effect of the sea-bottom, transmitted across horizontal sections, is less than that of the neighbouring water, transmitted across vertical sections. But it is possible that the pressure-gradients have not been correctly determined.

G II 4

Some Calculations of Vertical Velocity and Turbulence in the North Pacific near Southern California

By

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Vertical velocity and turbulence are computed from serial observations of temperature within 150 meters from the surface at stations in the Pacific Ocean off Southern California. All computations are based upon the fundamental differential equation,

$$\frac{\partial \theta}{\partial t} = b^2 \frac{\partial^2 \theta}{\partial y^2} - V \frac{\partial \theta}{\partial y}.$$

After suitable grouping of the observations with respect to time at each depth, values corresponding to a uniform time interval of two weeks are computed by means of divided differences. An elementary method based upon the direct calculations from the adjusted data of the three derivatives is used first. While, in general, numerical values of these derivatives at two different depths should suffice to determine both b^2 and V, the rather high variability of derivatives is, in practice, reduced by integrating numerically with respect to depth over two to four intervals. Each such equation is divided by the coefficient of b^2 or of V. The resulting ratios provide in either case a set of points which determine a straight line whose parameters are b^2 and V.

Another method is to fit the temperatures as well as their time derivatives to depths using two exponential functions of the depths for each. The first term of the differential equation is replaced by the empirical exponential formula for

the time derivative. Values of b^2 and V are easily expressed in terms of the known constants in the solution of the resulting ordinary differential equation involving temperature and depth.

Integrating the differential equation with respect to time between suitable limits reduces the first member to the difference between two temperatures at these times and at any depth. The second member is readily integrated with respect to time by means of numerical values of the temperature depth derivatives. Division of each such equation by the coefficients of b^2 or V provides in either case, as before, co-ordinates of a set of points which determine a straight line whose parameters are b^2 and V.

Finally the differential equation is solved subject to the following boundary conditions: When the time is zero, θ is a known exponential function of depth, and at a given depth, θ has a known value at each of a series of values of the time. Substitution in this solution of values of b^2 and V, assumed or approximately computed by previous methods, permits calculation of the serial temperatures at the series of times, for comparison with observations.

The same procedure applied to the salinity and hydrogen ion concentration provides independent estimates of the coefficient of turbulence and velocity, for comparison.

G III 1·1

Wind-Circulation of Water and the Inertia Terms

By

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This study on the wind circulation of water may be summarised as follows:—

(1) The hydrodynamical equations were integrated on the assumption that a stationary wind exerts a constant tangential stress T on the surface of water in a rectangular tank of depth H. The boundary conditions were that the components of velocity across and along the side walls and bottom were zero. The method of Cowley-Levy was used together with F. Wolf's numerical method of integration of partial differential equations, and we took the inertia terms into account. Neither omission nor inevitable assumption on the vertical and horizontal currents was made.

(2) The stream function obtained $\psi(x, z)$ was of the form:

$$\psi(x, z) = \psi_0(x, z) + \psi_1(x, z)C + \psi_2(x, z)C^2 + \ldots$$

where $C = TH^2\kappa/n^2$, n being the coefficient of eddy viscosity and κ the density of the water. If $C \leqq 100$, the solution can be sensibly given by $\psi(x, z) = \psi_0(x, z) + \psi_1(x, z)C$, neglecting $\psi_2(x, z)C^2$ and higher terms. The functions $\psi_0(x, z)$, $\psi_1(x, z)$ were evaluated.

(3) We examined the change in the manner of circulation from the stream lines in the motions for different values of C, and compared the results with the cases probably occurring in nature. The motion becomes slower as C increases.

(4) The water surface rises leewards and falls windwards. The relation between such a change in height and C was

examined and we found that the difference in the water height at both ends of the basin decreases as C increases.

Though the investigation was made exclusively by Wolf's method, a better method may be found. The numerical calculations required a computer of normal ability for about one year and a half, with six working hours every day.

We assumed that the longitudinal section of the basin was rectangular. But the numerical method does not necessarily require this figure, and a solution can be obtained for any distribution of depth along the basin.

G III 1·2

Resolution
of
The International Meteorological Committee

Passed September 1937

In view of the importance to climatology and oceanography of the exchange of heat between the surface of the sea and the lowest layer of the atmosphere, and also of the amount of heat stored below that surface, *i.e.* in the water, during spring and summer and given off during autumn and early winter, the Committee recommends that measurements of the radiant energy transferred to the sea and its heating effects in the water be carried out by oceanographers and meteorologists in co-operation.

G IV 1·1

Studies on Ocean Waves by Stereoscopic and Cinematographic Methods

By

K. HIDAKA

Imperial Marine Observatory, Kōbe

Certain wind-waves and swells were photographed by a stereoscopic camera, specially designed and set on board the M.S. "*Ryōhū Maru*," the surveying ship belonging to the Central Meteorological Observatory, Tokyo. The base-line, or the distance between the optical axes of two lenses, was 6 metres; the negatives obtained were read by a stereocomparator of the Pulfrich type, and the contour lines of the surface of the sea were then drawn. At the present time, the form of the waves over an area of a shape of an equilateral triangle with one side about 200 metres can be determined.

Besides the above methods, a cinematographic camera was used. Froude's apparatus was photographed by a cine-camera, and the scale of Froude's apparatus in the film was read by means of a magnifying glass. By this method the heights and periods of waves can be determined very accurately.

Further detailed studies on these materials are promised.

G V

Antrag

Von

O. PRATJE

Hamburg

Es wird vorgeschlagen zu beantragen, daß als Verhandlungspunkt auf die Tagesordnung gesetzt werde: "Die Abbildungsmöglichkeiten der physikalischen und chemischen Eigenschaften des Ozeanwassers in den Sedimenten am Meeresboden."

Die ozeanographischen Beobachtungen in einem Ozean liegen nie so dicht, daß sie nicht noch Ergänzungen vertragen können, und als Hilfsmittel können mit gutem Erfolge die Sedimente herangezogen werden. Die Sedimente der Ozeane sind, nachdem mit zunehmender Entfernung von der Küste die Einflüsse des festen Landes immer geringer geworden sind, fast ausschließlich von den Faktoren im Ozean abhängig. Da sprechen die Strömungsgeschwindigkeiten und die Turbulenz am Meeresboden mit, der Gasgehalt und die Temperatur des Meerwassers und damit seine Lösungsfähigkeit, die Oberflächenströmungen, welche die Träger des Lebens sind und damit die für die Anhäufung der Sedimente wichtigen organischen Schalen und Skelette liefern. Auch die im Auftriebwasser gelösten Nährstoffe spiegeln sich am Meeresboden in den Organismenresten wieder. Ein Beispiel aus dem Südatlantischen Ozean: Im Brasilbecken sind geringe Kalkgehaltswerte, im Angolabecken in der gleichen Breite und Tiefe hohe. In das Brasilbecken dringt der kalkauflösende antarktische Bodenstrom ein, aus dem Angolabecken wird er durch den Walfischrücken abgesperrt. Der Durchlaß zum Brasilbecken kann nicht, wie die Sedimente zeigen, an der mittelatlantischen Schwelle liegen—das ist von ozeanographischer Seite erwogen worden—, sondern muß an der brasilianischen Seite sich einschneiden.

Da die Sedimentation am Ozeanboden sehr langsam vor sich geht (vielfach weniger als 0·5 cm. in 1000 Jahren), stellen die Ablagerungen gewissermaßen ein langjähriges Mittel der Wassereigenschaften dar. Bei der großen Fülle der oft gleichzeitig wirkenden Faktoren ist es nicht immer möglich, sie ohne weiteres in den Sedimenten wiederzuerkennen. Vielmehr muß man zunächst die Fälle untersuchen, wo ein Faktor oder eine Gruppe überwiegt, um so den Einfluß zu erkennen. Es erscheint zweckmäßig, wenn in einem internationalen Kreise die in den verschiedensten Meeren gemachten Beobachtungen mitgeteilt werden, um so zu einem Gesamtbild beizutragen. Aus der Summe derartiger Beobachtungen wird man zu einer zuverlässigen Ausdeutbarkeit der Sedimente sowohl für geophysikalische wie für geologische Zwecke kommen.

G VI

Langjährige Änderungen der mittleren Wasserstände

Antrag

Von

A. WECHMANN

Landesanstalt für Gewässerkunde und Hauptnivellements, Berlin

Zur einheitlichen Durchführung und Bearbeitung von Wasserstandsbeobachtungen an den Küsten der Ozeane wurde, einem Vorschlag von Herrn R. Witting entsprechend, auf der 5. Generalversammlung der Internationalen Vereinigung für Geodäsie und Geophysik in Lissabon im September 1933 innerhalb der Gesellschaft für physikalische Ozeanographie das "Committee on Mean Sea-level and its Variations" gebildet. Die Zusammenarbeit mit Vertretern der Gesellschaft für Geodäsie und des "International Hydrographic Bureau of Monaco" wurde sichergestellt. Die Arbeit des genannten Committees ist inzwischen vor allem darauf gerichtet gewesen, einerseits die vorhandenen Reihen von Wasserstandsbeobachtungen nachzuweisen und zu sammeln mit dem Ziele, sie zu veröffentlichen, andererseits darauf hinzuwirken, daß ein über alle Meere sich erstreckendes ständiges Netz von Pegelstationen geschaffen wird, von denen die Wasserstandsbeobachtungen für allgemeine Zwecke nach einheitlichen Gesichtspunkten besonders sorgfältig ausgeführt und veröffentlicht werden sollen.

Es wird damit ein wertvolles Beobachtungsmaterial geschaffen, das geeignet ist, unter anderem für die verschiedensten Meeresküsten die wichtige Frage langjähriger Änderungen der mittleren Wasserstände zu untersuchen. Für einzelne Küstenabschnitte ist diese Frage bereits eingehend behandelt worden. Sobald jedoch die Ursachen der festgestellten langjährigen

Wasserstandsänderungen erörtert werden, erweist es sich als notwendig, die Wasserstandsbeobachtungen von anderen Küsten in die Betrachtungen einzubeziehen.

Für das begrenzte Gebiet der Ostsee ist die Frage langjähriger Änderungen des Mittelwassers zum Beispiel im Verhandlungspunkt 13 der VI. Baltischen Hydrologischen Konferenz 1938 zur Sprache gekommen. Der zu diesem Punkt eingereichte deutsche Länderbericht ergab zunächst, daß bei kritischer Betrachtung auch alte, weit zurückreichende Reihen von Wasserstandsbeobachtungen zu einem wertvollen, unentbehrlichen Beobachtungsmaterial werden können. Nur unter Benutzung solcher älteren Beobachtungen gelang es dann zu zeigen, daß die Wasserstände an der deutschen Ostseeküste nach dem Jahrzehnt 1881/90, abweichend von ihrem Verhalten vor dieser Zeit, ein deutliches Ansteigen aufweisen; es zeigte sich, daß dieses Ansteigen wahrscheinlich im Zusammenhang steht mit meteorologisch-ozeanographischen Einwirkungen, die außerhalb des Ostseegebiets ihren Ursprung haben. Zur weiteren Klärung der behandelten Frage müßten daher auch entsprechende langjährige Wasserstandsbeobachtungen außerhalb des Ostseegebiets herangezogen werden. Da die Fragen, die mit der Analyse der im Ostseeraum bisher bearbeiteten Wasserstandsbeobachtungen verbunden sind, noch keineswegs umfassend geklärt sind, wurde beschlossen, sie auch zum Verhandlungspunkt der VII. Baltischen Hydrologischen Konferenz zu machen.

Die verschiedenen möglichen Ursachen langjähriger Wasserstandsänderungen haben zumeist eine voneinander verschiedene räumliche und zeitliche Auswirkung, so daß bei einer Untersuchung langer Beobachtungsreihen über weite Gebiete ihre genauere Erforschung und bei Überlagerung mehrerer Vorgänge auch deren Trennung voneinander bis zu einem gewissen Grade möglich sein wird. So unterliegen zum Beispiel die Krustenbewegungen in Nordeuropa bestimmten geologischen Gesetzmäßigkeiten. Langjährige Änderungen der Luftdruck- und Windverhältnisse, wie sie im Bereich des nordatlantischen Zirkulationssystems festgestellt worden sind, werden Wasserstandsänderungen zur Folge haben, die an der europäischen Westküste und der nordamerikanischen Ostküste nicht analog

verlaufen. Soweit dagegen etwa durch Änderungen in der Vereisung der Pole Änderungen der Gesamtwassermenge der Ozeane und damit meßbare eustatische Änderungen des Meeresspiegels hervorgerufen werden, ist an allen Meeresküsten ein relativ gleichsinniges Verhalten des Mittelwassers zu erwarten. Wieder anders wirken auf das Mittelwasser Vorgänge, die Änderungen der Gleichgewichtsfigur der Erde betreffen. Falls das an der deutschen Ostseeküste festgestellte Ansteigen der Wasserstände etwa seit dem Jahrzehnt 1881/90 eine allgemeine, nicht durch örtlich begrenzte Bodenbewegungen bedingte Erscheinung ist, muß sich diese daher auch an entfernteren Küsten bemerkbar machen, wo entsprechend andere geologische Verhältnisse vorliegen. In der Tat ergibt sich bei Nachprüfung einer Anzahl längerer Beobachtungsreihen von europäischen Küsten, die bisher durch Veröffentlichungen bekannt geworden sind, daß Anzeichen für ein solches allgemeines Ansteigen des Mittelwassers seit der zweiten Hälfte des 19. Jahrhunderts vorliegen.

Die Bearbeitung des gesamten vorhandenen Beobachtungsmaterials hinsichtlich der Frage langjähriger Änderungen der mittleren Wasserstände wäre aus den genannten Gründen sehr erwünscht. Aus einer solchen Bearbeitung würden sich auch wertvolle Gesichtspunkte für die weitere Zusammenstellung des Beobachtungsmaterials ergeben. Im Hinblick auf den gegenwärtigen Stand der Forschung ist sie besonders dringlich für die Küsten des Atlantischen und Pazifischen Ozeans einschließlich einiger Nebenmeere. Die Untersuchungen müßten sich, soweit die Beobachtungen entsprechend ausgewertet werden können, auch auf das Tidehochwasser und das Tideniedrigwasser beziehen, um zugleich die langjährigen Änderungen des Tidehubs ermitteln zu können.

Es wird daher beantragt, auf die Tagesordnung der nächstfolgenden Versammlung der Internationalen Vereinigung für Geodäsie und Geophysik das Thema zu setzen:

> Untersuchungen darüber, ob langjährige Änderungen der mittleren Wasserstände (Tidehochwasser, Tideniedrigwasser, Tidemittelwasser) an den Küsten des Atlantischen und des Pazifischen Ozeans festzustellen sind und wie sie erklärt werden können.

Das "Committee on Mean Sea-level and its Variations," dem das Beobachtungsmaterial zum großen Teil zur Verfügung steht, würde zweckmäßigerweise hierzu die geeigneten Schritte unternehmen, um die gemeinsame Bearbeitung sicherzustellen. Für den Fall, daß die einzelnen Länder zu Berichten über diese Frage aufgefordert werden sollen, werden noch einheitliche Richtlinien für die Bearbeitung aufgestellt werden müssen.

Der Antrag wird zugleich in der Gesellschaft für physikalische Ozeanographie und in der Gesellschaft für wissenschaftliche Hydrologie gestellt, da beide Gesellschaften an ihm interessiert sind.

C VII

Chemische Wasseruntersuchung und Nomenklatur im Übergangsgebiet vom Meer zum Süßwasser

Von

H. WATTENBERG

Meereschemisches Laboratorium der Universität, Kiel

Für das Meerwasser sind dank der Bemühungen des *Conseil international pour l'exploration de la mer* und der IGGV (vergl. Beschluß der Union in Edinburgh) für eine große Anzahl der wichtigsten Bestimmungsgrößen einheitliche Untersuchungsmethoden und eine einheitliche Nomenklatur international vereinbart worden. Andererseits sind für die Untersuchung der Landwässer, besonders soweit sie sich auf technisch und hygienisch wichtige Eigenschaften beziehen, genormte Untersuchungsmethoden ausgearbeitet. Die Verfahren sind jedoch jeweils ausschließlich für das entsprechende Milieu, d.h. für das Meerwasser oder das Süßwasser zugeschnitten und nicht von einem auf das andere Medium übertragbar. Da sie vielfach von den praktischen Erfordernissen ausgehen und sich oft auf rein empirische Meßgrößen beziehen, sind auch die Ergebnisse für See- und Süßwasser nicht miteinander vergleichbar. Ein besonders wichtiges Beispiel dafür bilden die verschiedenen Kohlensäurefaktoren.

An der Grenze zwischen Meer und Landwässern und in ihren Mischgebieten, also an Flußmündungen, in Lagunen und anderen Brackwassergebieten, wie z.B. in einem großen Teil der Ostsee, kann man nun im Zweifel sein, welche der erwähnten Methoden man anzuwenden hat. Man wird bei Anwendung der Süßwasser- bezw. Seewasser-Verfahren auf das Brackwasser zu verschiedenen Ergebnissen kommen.

Besonders erschwert wird die Vergleichbarkeit von Werten aus den verschiedenen Gebieten dadurch, daß sich in beiden

Bereichen eigene Nomenklaturen herausgebildet haben, die sich z.T. von rein praktischen Gesichtspunkten aus entwickelt haben. Ein einwandfreier Vergleich wäre aber nur dann möglich, wenn man von den in der physikalischen Chemie festgelegten Bezeichnungsweisen und Begriffen ausgeht.

Es wird daher vorgeschlagen zu prüfen, inwieweit eine Vereinheitlichung der für Meerwasser und Süßwasser angewendeten Methoden und Bezeichnungen möglich ist. Als erster Schritt wäre eine Gegenüberstellung der in den beiden Bereichen gebräuchlichen Verfahren und Nomenklaturen zu empfehlen, durch die eine Übertragung der Ergebnisse von einem zum anderen System erleichtert würde. Wie bereits erwähnt, käme vor allem ein Vergleich der Methoden und Bezeichnungen der Kohlensäurefaktoren, der Alkalinität und Kalklöslichkeit und des Salzgehalts in Betracht.

H 1

The Work carried out by the International Hydrographic Bureau

By

J. D. NARES

President of the Directing Committee

These remarks will generally be confined to the progress of work carried out by the International Hydrographic Bureau since the General Assembly at Edinburgh in September 1936.

(*a*) A short account will be given of the International Hydrographic Conference held at Monaco in April 1936.

(*b*) The progress of work of preparation of the 3rd Edition of the General Bathymetric Chart of the Oceans.

(*c*) Work carried out in connection with the "Committee on the Criteria and Nomenclature of the major divisions of the Ocean Bottom." (Note: a detailed report of this Committee is being presented by the Chairman.)

(*d*) Work carried out in connection with the "Committee on Mean Sea-Level and its Variations."

(*e*) The work of centralisation of Oceanic Soundings and plotting of same on a series of 1001 sheets.

(*f*) Compilation of a Dictionary of Hydrographic Terms.

(*g*) Other activities of the Bureau.

H 3

Rapport d'ensemble sur les travaux d'Océanographie physique effectués en France de Septembre 1936 à Septembre 1939

Par

L. PÉLISSIER

Ingénieur hydrographe, Secrétaire de la Section d'Océanographie physique du Comité National Français

I

Il y a 3 ans, le jour où commençait à Edimbourg la 6ème Assemblée Générale de l'Union Géodésique et Géophysique International, au cours de la séance d'ouverture, le Professeur D'Arcy Wentworth Thompson annonçait aux Congressistes la perte du "Pourquoi-pas?", la mort tragique de J. B. Charcot et celle de ses compagnons,* survenues le 16 Septembre aux premières heures du jour, en Islande, devant la pointe d'Alftanès située à 20 milles dans le N.N.W. de Reykiavik.

Depuis cette époque la Section d'Océanographie physique du Comité national français a été fréquemment et durement éprouvée, perdant successivement: Henri Watier, le 24 Avril 1937, Charles Lallemand, ancien Président de l'Union, le 2 Février 1938, Pierre Marti, le 5 Décembre 1938 et, tout récemment le 18 Juillet 1939, Eugène Fichot, Vice-Président de l'Association Internationale d'Océanographie physique. A cette liste, il y a lieu d'ajouter deux de nos anciens collègues, le Contre-Amiral Le Leon et M. L. de Launay membre de l'Institut, décédés respectivement le 30 Septembre 1937 et le 30 Juin 1938.

Par suite de l'importance de leur œuvre Océanographique nous donnerons une mention particulière à Pierre Marti et à Eugène Fichot.

* 39 sur 40 ont péri ce jour là à 5 heures du matin.

Pierre MARTI, qui vient de nous être enlevé à 47 ans en pleine maturité d'esprit, en pleine production scientifique, était sans conteste, l'un des plus éminents hydrographes et océanographes français de l'époque actuelle. A une activité professionnelle considérable, qui s'est manifestée par l'exécution d'un grand nombre de levés hydrographiques, sur les côtes de la métropole et des colonies, il ajouta de magnifiques travaux sur le sondage et sur le repérage par le son. L'étude bathymétrique des océans lui doit des progrès de grande importance. Il fut l'un des premiers, dans le domaine du sondage par le son, à aboutir à des résultats. En mai 1919 il obtenait les premiers sondages acoustiques exécutés en France et en Août 1919 à bord du navire câblier "CHARENTE" à la vitesse de 9 nœuds, il sondait jusqu'à plus de 4,000 mètres de profondeur au moyen de cartouches détonantes contenant seulement 40 grammes d'explosif, En Avril 1922 lors de l'exploration du trajet d'un câble sous marin, Marseille Philippeville, il effectua un profit de sondage acoustique en utilisant son procédé de production de l'onde élastique par la pénétration d'une balle de fusil ou de canon dans l'eau. Son activité scientifique était à la hauteur de son activité professionnelle et technique. Désigné pour collaborer aux études de pesanteur sur mer, après avoir reçu les renseignements de M. VERNING MEINESZ, il devint à son tour un maître dans ce domaine. Les résultats obtenus, sous sa direction, sur les sous-marins "FRESNEL" et "ESPOIR" font l'objet d'une communication du Service hydrographique français à la présente assemblée générale de l'Union.

Eugène FICHOT fut un remarquable technicien et un savant distingué. L'Académie des Sciences l'avait accueilli parmi ses membres, dans la Section de Géographie et Navigation, le 2 Février 1925. Dans la séance du 24 Juillet 1939, le Président de l'Académie des Sciences, en prononçant l'éloge funèbre de cet hydrographe éminent, faisait remarquer que son activité s'était déployée dans de nombreux domaines: en hydrographie, en géodésie, en géographie, en physique du globe, dans la théorie du phénomène des marées, dans l'étude pratique de l'utilisation de ce phénomène, et, d'une façon moins régulière, en météorologie, en géologie et en volcanologie. En géodésie E. FICHOT a mené à bien, d'une façon brillante, de

difficiles recherches. Mais son œuvre capitale se rattache à la théorie des marées. En 1910 Henri POINCARE avait professé, dans son cours de mécanique céleste de la Sorbonne, de remarquables leçons sur les marées. La mise au point et la rédaction élégante et claire de ce cours qui constitue le tome III des "Leçons de Mécanique céleste," hélas inachevées, du grand mathématicien français, sont dues à E. FICHOT qui, à partir de cette époque, publia sur la théorie des marées une vingtaine de notes et de mémoires. Il convient de signaler particulièrement: l'ouvrage qu'il a publié en 1923 sous le titre "Les marées et leur utilisation industrielle," le fascicule "Marées océaniques et marées internes, publié, en partie seulement, dans l'encyclopédie des sciences mathématiques, enfin sa dernière œuvre "Exposé critique sur la théorie des marées." Ce magistral exposé devait, d'après les intentions de l'auteur, comporter 7 chapitres. Les 3 premiers ont été publiés en 1938, dans les Annales du Bureau des Longitudes et comprennent la partie capitale de l'ouvrage (chapitre 3, Théorie des marées océaniques). Les deux suivants sont entièrement rédigés et prêts pour l'impression. Ils doivent paraître dans les Annales du Bureau des Longitudes. Les Chapitres VI (marées dans les rivières) et VII (marées de l'écorce terrestre) sont probablement inachevés.

II. TRAVAUX

Une revue complète des travaux océanographiques effectués en France depuis 1936 comporterait des développements d'une certaine longueur. On se bornera à énumérer les résultats les plus importants.

(*a*) Avec le "POURQUOI-PAS"? ont disparu les données recueillies par J. B. CHARCOT et ses collaborateurs au cours de la campagne de 1936. Grâce à une "absence totale, exceptionnelle, inexplicable de glaces marines" des sondages avaient pu être effectués à l'emplacement habituel de la banquise. Par un croquis hativement dessiné par J. B. CHARCOT, nous avons su combien ces sondages eussent présenté d'intérêt et d'importance.

Le Service Hydrographique a publié, dans ses Annales, le rapport sommaire que J. B. CHARCOT avait expédié de Reykiavik, probablement le 6 Septembre, et dans lequel sont

résumés brièvement les évènements qui ont précédé le drame du 16 Septembre.

(*b*) Le navire océanographe "PRESIDENT THEODORE TISSIER" terminait sa 6eme croisière à l'époque de l'Assemblée Générale d'Edimbourg. Les résultats bathymétriques et hydrologiques et une partie des recherches sur les poissons des 5 premières croisières ont été publiés en 4 livraisons dans la Revue des Travaux de l'Office des Pêches Maritimes (Tome IX fascicule 2 de 1936 et Tome X fascicule 2, 3 et 4 de 1937). Un plan en relief de la "fosse du Cap Breton," établi d'après le levé effectué au cours de la 4ème croisière (1935) a été présenté par l'Office des Pêches à l'Exposition Internationale "Arts et Techniques" Paris 1937.

Pendant les années 1937 et 1938, le "PRESIDENT THEODORE TISSIER" n'a pas pris la mer. En 1939, à la suite d'une entente entre le Ministre de la Marine et l'Office, les croisières de ce navire ont été réorganisées. Le navire sera armé en principe de Mars à Novembre par la Marine Militaire. Une croisière d'essai est en cours cette année sous la direction du Service Hydrographique qui a entrepris, sur les côtes Occidentales de France la reconnaissance du plateau continental des pentes de ce plateau jusqu'à l'isobathe de 4,500 mètres. Cette reconnaissance comprend la relève détaillée du relief sous-marin, des mesures hydrologiques (température, salinité, pH . . .), l'observation, sur toute l'étendu du plateau, jusqu'à l'isobathe de 200 mètres, des marées à l'aide du marégraphe Favé et des courants au point fixe à diverses profondeurs. Cette étude systématique doit être poursuivie par le Service Hydrographique au cours des années à venir. Chaque année d'autres croisières seront effectuées sous la direction de l'Office Scientifique et Technique des Pêches Maritimes qui orientera plus spécialement ses recherches dans le domaine des pêches et de l'océanographie biologique.

(*c*) Le Service des Cables sous-marins a obtenu par des sondages à l'ultra-son en 1936, et a communiqué ultérieurement au Service Hydrographique, des données intéressantes qui ont complèté la connaissance sur le relief du seuil sous-marin reliant, par profondeurs inférieures à 500 mètres, la Sicile à la Tunisie. Ce seuil est traversé de crêtes et de sillons dont la

disposition, le nombre et l'étendue ont été précisés à la suite de cette reconnaissance.

(*d*) Le navire météorologique stationnaire "CARIMARE" de l'Office National Météorologique a étudié, en Juin 1938 et en Mai 1939, les abords du Gulf Stream entre les Açores et Terre-Neuve, en effectuant les observations suivantes: mesures de la température de la mer en surface et de la température de l'air, prélèvement d'échantillons d'eau de mer en surface, détermination du courant par observations astronomiques. Ces observations se relient aux travaux des navires océanographes qui ont commencé à la suite des propositions faites à l'Assemblée Générale d'Edimbourg l'exécution du programme d'études hydrologiques simultanées de l'aire compris entre l'Amérique et l'Europe.

(*e*) Plusieurs navires de la Compagnie Générale Transatlantique, de la Compagnie des Messageries Maritimes et de la Compagnie Paquet, munies de sondeurs acoustiques ou à U.S. ont apporté d'utiles contributions à la connaissance du relief sous-marin sur les routes qu'ils suivent habituellement. Une sonde de 1.850 mètres obtenues par le paquebot "FLANDRE" de la Transatlantique en Juin 1936 par 27° 50′ Nord a montré que l'isobathe de 3,000 m. se prolongeait beaucoup plus au sud qu'on ne le pensait. Ce résultat a été confirmé par de nouvelles sondes reproduites dans la Revue Hydrographique de Novembre 1938 qui a publié un rectificatif de la feuille A, comprenant les résultats de paquebot "FLANDRE." Le "Félix Roussel" et l'"Aramis" des Messageries Maritimes ont découvert, dans le voisinage des Paracels, plusieurs collines sous marines des plus remarquables. Une sonde de 417 mètres entourée de sondes de plus de 1,000 mètres a été récemment étudiée en détail par le bâtiment hydrographe britannique "HERALD" qui a déterminé l'isobathe de 1,000 mètres et a obtenu une profondeur de 411 mètres sur le sommet. Un autre navire des Messageries Maritimes, le "PRESIDENT DOUMER" a étudié au cours de plusieurs traversées à 70 milles à l'Ouest de la tête d'Achem un sommet remarquable de 220 mètres entouré de sondes de plus de 1,000 mètres. Une sonde de 327 mètres avait été trouvée dans le voisinage en 1937 par le navire hydrographe britannique "STOCK." L'"EMDEN" en

1928 avait obtenu une sonde 814 à moins de 20 milles du sommet.

(*f*) L'activité, dans le domaine de l'Hydrographie et de l'Oceanographie, des missions hydrographiques et de certains avisos coloniaux ne s'est pas ralentie. En outre, quelques données bathymétriques intéressantes ont été obtenues par des navires de la flotte au cours de leurs croisières.

En Indochine, la reconnaissance des Golfes du Tonkin et de Siam s'est poursuivie et a permis de constater que, dans les régions examinées, les nombreuses "vigies" du Golfe de Siam n'existaient probablement pas. En Tunisie il convient de signaler la belle exploration du banc des Esquerquis exécutée en 1937 sous la direction technique de M. Brunel Ingénieur hydrographe.

L'aviso "Rigault de Genouilly," au cours de sa navigation dans le Pacifique, dans le voisinage des Nouvelles Hébrides et des Iles de la Société a trouvé quelques bancs remarquables qui feront, ultérieurement, l'objet d'une étude plus complète.

L'aviso "Bougainville" a exécuté en 1939, du 11 Janvier au 12 Mars, une remarquable croisière dans les mers australes, Parti de Diégo-Suarez, il s'est ravitaillé à Durban, a visité l'île Marion, l'archipel de Crozet, l'archipel de Kerguelen, les îles Saint Paul et Amsterdam, et a rallié son point de départ après avoir touché La Réunion et Maurice. La croisière avait dans son programme une partie scientifique relative à la météorologie, à l'océanographie, à l'hydrographie, au magnétismes terrestres, aux parasites atmosphériques et à l'histoire naturelle. Des sondages par détonation (219 au total) ont été effectués tous les 30 milles en dehors des socles insulaires et des plateaux continentaux, tandis que sur ces socles eux même ou sur leurs premières pentes, jusqu'à quelques centaines de mètres de profondeur on a utilisé l'appareil de sondage U.S. à enregistrement continu (1 sonde toutes les 3 secondes). L'aviso a mesuré systématiquement la température de l'eau de mer et recueilli des échantillons de cette eau pendant toute la croisière à diverses profondeurs. De nombreux radio-sondages de l'atmosphère ont été effectués dans les îles. Contentons nous d'indiquer que le tracé des isobathes de la nouvelle édition de la Carte bathymétrique générale des Océans (feuille A' IV, 1er Juillet 1938, du Bureau

Hydrog. Internat.) s'est trouvé remarquablement confirmé par les sondages de l'aviso qui n'apportent à ces isobathes que de légères retouches. Signalons aussi l'existence à 30 milles vers le Nord de l'île aux Cochons (Crozet), en bordure du socle insulaire, d'une région chaotique parsemée de nombreux sommets dont les têtes sont recouvertes d'une centaine de mètres d'eau, au milieu de profondeurs de 200 à 220 mètres environ. Deux notes parues dans les comptes rendus de l'Académie des Sciences, l'une sur les radio-sondages dans la séance du 1er Mai 1939, l'autre sur les parasites atmosphériques, dans la séance du 10 Juillet 1939, indiquent les résultats fondamentaux obtenus dans ces deux domaines. Une autre note, qui sera insérée dans la Revue Hydrographique de Novembre 1939 du Bureau Hydrographique International, résume les résultats obtenus par le "Bougainville" dans l'étude du relief sous-marin par grande profondeur. Un rapport détaillé concernant l'hydrographie (positions astronomiques, observations magnétiques, levés), l'océanographie (bathymétrie et hydrologie), la météorologie (radiosondages et parasites atmosphériques) sera publié l'année prochaine dans les Annales Hydrographiques.

Aux abords des Açores, le relief sous-marin est particulièrement tourmenté. Entre la carte bathymétrique de Thoulet, publiée en 1903, et celle que le Service Hydrographique a établie en 1937, pour l'exposition Internationale de Paris "Arts et Techniques," à l'aide de tous les travaux postérieurs et particulièrement des sondages acoustiques du paquebot "Flandre" de la Transatlantique, il y a un progrès considérable. De nouvelles données intéressantes ont été recueillies dans ces parages depuis 1937, et, en particulier une sonde de 520 mètres trouvée par le cuirassé "Provence," au cours d'une de ses croisières, au milieu de profondeurs de 1,200 mètres, dans le voisinage d'une ancienne sonde de 982 mètres et à moins de 20 milles d'un haut fond douteux, vestige de l'éruption de 1720.

(*g*) Citons maintenant un travail d'un caractère différent concernant l'archéologie sous-marine qui a été exécutée sous la direction du R. P. Poidebard sur les côtes de Syrie. Nous énumérerons ensuite quelques travaux de laboratoire d'une réelle importance et quelques références bibliographiques.

Les travaux du R. P. Poidebard, au mouillage Sud de Sour, en vue de rechercher les traces du grand port antique de Tyr, ont été effectués de 1934 à 1936 avec divers concours, ceux de l'Aviation et de la Marine en particulier. A l'aide de photographies aériennes et de photographies sous-marines, en utilisant la lunette de calfat et les enquêtes de scaphandrier, le problème de l'ancien port de Tyr a été complètement résolu, le tracé des digues des brises-lames, des darses a été relevé et dans une certaine mesure le mode de construction des blocs, des moles et des quais a été reconstitué. Le R. P. Poidebard a publié sur ce sujet, dans la Revue Maritime de Juillet 1937, un article intitulé "L'ancien port de Tyr, Recherches sous-marines 1934–1936" article qu'il concluait ainsi: "L'avion doit être considéré maintenant comme un instrument essentiel dans les recherches des ruines sous-marines."

Dans les comptes rendus (séances du 12 Décembre 1938), M. Gabriel Bertrand, membre de l'Académie des Sciences, a exposé brièvement la méthode qu'il a employée pour déterminer la proportion, non encore connue exactement, du zinc contenu dans l'eau de mer. Grace à sa méthode si sensible et si précise de séparation des moindres traces de zinc, dans une solution minérale complexe, par la chaux et l'amoniaque, et en ajoutant à l'échantillon d'eau de mer une quantité convenable de chlorure de baryum spécialement purifié, M. Marcel Bertrand a trouvé, par litre d'eau de mer en milligramme; 3,1 pour la mer du Nord—3,79 pour la Méditérranée—4,4 pour la mer Morte. Ces chiffres différent beaucoup de ceux trouvés jusqu'ici et reproduits, par exemple, dans le volume V (Océanography) du "Bulletin of the National Research Council" savoir en milligramme pour 1000 grammes d'eau 0,002 d'après Dieulafait—0,073 d'après Bodansky—0,1 dans la Manche d'après Orton.

Dans le même domaine de la chimie de la mer, M. J. Bardet A. Tchakinian, et Melle R. Lagrange ont trouvé 0,17 milligramme de lithium par litre, en opérant sur 200 litres d'eau prélevés au large de Roscoff. Ce chiffre est en accord avec celui trouvé par M. B. D. Thomas au moyen d'une méthode spectroscopique (0,1 milligramme par litre) d'après le "Bulletin of the National Research Council".

Il n'est pas sans intérêt de rappeler le procédé indiqué par

M. Georges Claude pour la recherche des avions perdus en mer et consistant à produire automatiquement une tache colorée de grande visibilité et de bonne stabilité (Comptes Rendus A.S. 3 Mai et 3 Nov. 1937).

M. Marcel Brillouin, Membre de l'Académie des Sciences, a mis en évidence dans une note insérée aux comptes rendus (7 Nov. 1938) les difficultés essentielles auxquelles se heurte la conception d'une surface de référence stable pour l'étude des marées.

Pour la mesure de la salinité de l'eau de mer, M. A. Roche, assistant au laboratoire du Commandant Rouch, professeur d'Océanographie physique à l'Institut Océanographique, vient de mettre au point un dispositif fondé sur la mesure de la conductivité du liquide (réalisation de l'équilibre dans un pont de Kohlrausch et capable de fournir la salinité avec une précison égale à celle de la méthode chlorimétrique. *Cf.* Bull. Inst. Océanog. n° 799 Août 1939).

Il n'est pas possible de donner une bibliographie complète des publications françaises relatives à l'Océanographie qui ont paru depuis Edimbourg. Contentons nous de signaler, en plus des notes et mémoires dont il a été question dans le présent rapport, les notes et mémoires suivants.

Distribution des pressions et vitèsses dans les lames déferlantes (P. Petry, Comptes Rendus A.S. 30 Août 1937).

Leçons d'Océanographie physique professées à l'Institut Océanographique en Février, Mars et Avril 1936 et publiées en 1937.

Etat actuel des études internationales sur les efforts dus aux lames (MM. de Rouville, Besson, Petry—Annales Ponts Chaussées, 1938).

L'Atlantique, Histoire et Vie d'un Océan (E. Le Danois. Paris 1938).

III

L'Océanographie physique est une Science relativement jeune. Cependant les questions qu'elle étudie ont préocupé les navigateurs depuis de nombreuses années. L'Océanographe moderne est heureusement surpris en constatant par exemple que le Chevalier de Kerguelen, d'après sa "Relation de deux

voyages dans les mers Australes et des Indes" mesurait en Décembre 1773 la salinité de l'eau de mer * dans le voisinage de l'archipel qu'il abordait pour la seconde fois et trouvait que cette salinité était de 41‰.

Sans remonter à une époque aussi ancienne, notons les centenaires de deux évènements remarquables pour l'Océanographie et l'Hydrographie.

C'est en 1838 qué l'hydrographe français BEAUTEMPS BEAUPRE termina l'œuvre du levé hydrographique des 2.000 Kilomètres des côtes Nord et Ouest de France. Cette œuvre avait duré de 1816 à 1838. Elle est représentée en 150 cartes formant 6 Atlas dont le dernier fut publié en 1844.† BEAUTEMPS BEAUPRE qui était né en 1766, dirigea effectivement et personnellement en mer, jusqu'à 72 ans, ces travaux qu'il avait entrepris à 50 ans; il ne fut mis à la retraite qu'en 1848, à 82 ans.

C'est en 1838 également que Georges AIME, né à Metz en 1811, ancien élève de l'Ecole Normale supérieure de Paris, fut nommé professeur de physique au Lycée d'Alger. Enthouiasmé par la mer, qu'il voyait pour la première fois, il résolut de l'étudier dès l'année 1838. De 1840 à 1842 sans fortune personnelle, sans ressources étrangères, il donna à ses travaux un très grand développement et fut un génial précurseur en Océanographie Physique et en Biologie Marine. Il mourut prématurément en 1846. Il avait découvert le benthon marin, en 1842, et imaginé le procédé du messager qui permet de faire manœuvrer les instruments plongés dans la mer et attachés à une seule corde, aussi facilement qu'à la surface de l'eau.

* L'histoire physique de la Mer de Marigli est de 1710.

† Les observations sont contenues dans des cahiers reliés en 527 volumes qui sont conservés au Service Hydrographique.

H 3·1

Oceanographic Activities of the United States Hydrographic Office

By

G. S. BRYAN
Captain, U.S. Navy

Since the Assembly of this body in 1936, the Hydrographic Office of the United States Navy has actively continued to contribute to the advancement of oceanography whenever possible.

The investigations may be divided into three broad fields, namely, delineating the configuration of the ocean floor, conducting dynamic oceanographical surveys, and the compilation of ocean current and surface sea-water temperatures.

The U.S.S. *Hannibal* has conducted hydrographic surveys on the east coast of Central America from the Atlantic entrance to the Panama Canal as far northward as San Juan del Norte. This vessel also surveyed the mouth of the Orinoco River and a portion of the north coast of Venezuela between the mouth of the Unare River and Ercarcero Point, including the off-lying islands.

The U.S.S. *Nokomis* continued survey operations along the north coast of Colombia completing the area between Santa Marta and Punta San Bernardo. At the end of the 1937 season the *Nokomis* was replaced by the U.S.S. *Bushnell*, which vessel during the next season completed a survey of the Colombian coast from Punta San Bernardo westward to Punta Carreto in Panama, including the Gulf of Darien. These surveys, covering an area of over 31,000 square miles, and utilizing aerial photography in the delineation of the coastline and adjacent topography, will result in the production of up-to-date charts for regions which heretofore were very imperfectly known, as

existing charts were based on Spanish sketch surveys over a century old.

Among the interesting oceanographical features developed during these survey operations was the development by the U.S.S. *Hannibal* of a submarine mesa, lying about 27 miles northwestward from Colon, Panama. This mesa has an area of $30\frac{1}{2}$ square nautical miles, is oval in shape and rises abruptly from an average general surrounding depth of about 200 fathoms to a least depth of 28 fathoms. On the north side it is an almost sheer cliff rising from 400 fathoms in a little over a mile. The profiles indicate that it is somewhat similar in shape to Coseguina Volcano, Nicaragua, thus leading to the assumption that it may be the crater of a former volcano. This belief is strengthened by the apparent crest around its rim and by the deep in its centre. Over 2000 soundings, accurately fixed for position, were observed in developing this interesting geological formation which has been named Banco Volcan.

During the past year naval vessels, exclusive of survey ships, obtained over 46,000 sonic soundings, mostly in regions previously unsounded. The U.S.S. *Ramapo* alone, in six passages, made 6804 soundings, which combined with the prior soundings taken by that vessel in this area amount to 35,976 soundings in 50 passages. It is of interest to note that during routine sonic sounding observations, the U.S.S. *Milwaukee* early this year discovered at two slightly separated points, the greatest depth yet recorded in the North Atlantic Ocean, namely 4780 fathoms (uncorrected) in the Brownson Deep off Puerto Rico. Using the same formula as on our Caribbean chart, the corrected depth is 5041 fathoms.

From the wealth of data received, the Hydrographic Office has since the 1936 meeting of this Association compiled and published large scale bathymetric charts of the North and South Pacific Ocean and of the Caribbean Sea.

The Hydrographic Office has continued to publish Lists of Oceanic Depths (H.O. Pub. No. 210 Series) containing lists of soundings taken by various naval units in the several oceans. Since 1936 three of these publications have appeared, namely 210 f, 210 g, and 210 h.

In the field of dynamic oceanographic surveys since 1936

a total of 96 stations have been occupied along the north coasts of Costa Rica, Panama, and Colombia by the U.S.S. *Hannibal* and U.S.S. *Bushnell*. The data obtained were forwarded to the Bingham Oceanographical Laboratories, Yale University, for use in conjunction with its investigations in that area. On a request by the President of the National Academy of Science the U.S.S. *Louisville*, in a passage from San Pedro to Pearl Harbour, T.H., occupied ten stations on a line closely paralleling one previously run by the *Carnegie*. Dr. E. G. Moberg and R. Doescher of the Scripps Institution of Oceanography accompanied the *Louisville* on this passage. In co-operation with the Scripps Institution the U.S.S. *Bushnell* occupied a line of dynamic stations between Balboa and San Diego, and another line from San Diego to the Hawaiian Islands.

In addition to actual surveys undertaken by naval vessels the Hydrographic Office has loaned dynamic sounding equipment to the University of Virginia National Geographic Expedition, which leaves shortly to investigate waters in the central Pacific, and to the forthcoming Byrd Antarctic Expedition.

As reported at the 1936 meeting of this Association, during that year a government sponsored project was commenced in San Pedro to evaluate the oceanographic data referring to the Pacific Ocean for a ten-year period. So successful was that project that the Hydrographic Office was able to extend similar activities to New Orleans and Philadelphia and to increase the scope of the project to include all oceans. Briefly, the plan is to enter all acceptable observations of ocean currents and sea-surface temperature observations, received in the Hydrographic Office since 1900, on punched cards, each card representing one observation. Then by mechanical methods these cards are sorted into months and years and desired areas for both current and temperature data. After the final sorting the cards are run through an electric tabulator which prints the information referring to each degree of latitude and longitude. Thus from the original mass of unrelated data there results a series of tabulation books containing all information systematically recorded. The magnitude

of the task may be realized from the fact that about five million observations are being considered. At the present time all observations have been punched, and those for the Pacific Ocean sorted and tabulated. It is expected that those observations relating to the Atlantic and Indian Oceans will be completed early next year. From this vast reservoir of correlated data a series of ocean current and sea-surface water temperature charts are being prepared by the Hydrographic Office, which should prove of great assistance to scientists in solving many of the existing problems relating to oceanic circulation, atmospheric and climatic conditions, and related questions. The first temperature chart has just been completed; it embraces the eastern portion of the North Pacific Ocean, and shows for each one-degree quadrangle, the maximum, the minimum, and average temperature recorded for a thirty-year period during the month of January.

The Hydrographer assures delegates that the Office welcomes the opportunity of making available any information that it may possess that would be of assistance to the Association in the pursuit of its investigations.

H 3'2

Oceanographic Activities of the U.S. Coast and Geodetic Survey

By

L. O. COLBERT

Rear Admiral; Director, U.S. Coast and Geodetic Survey

In this report there is reviewed briefly the oceanographic activities of the Coast and Geodetic Survey during the past three years. The basic off-shore surveys of the Atlantic coast of the United States have been completed from the Virginia Capes to the eastern border of Georges Bank; in the Gulf of Mexico, from the Mississippi River to the Mexican Border; and along the Pacific coast of the United States. Considerable progress has been made in the difficult surveys of the Aleutian Islands of Alaska, and also in the Philippines, Hawaiian, and Virgin Islands. In all these surveys the modern methods of echo sounding and radio acoustic ranging have been widely used.

In its tidal work the Survey now is operating nearly one hundred tide gauges, forty-six of which are at primary tide stations. Of these primary tide stations 26 are on the Atlantic coast, 5 on the Gulf coast, 12 on the Pacific coast, 2 in Alaska, and 1 in the Hawaiian Islands. In this work the Survey has been receiving the co-operation of the various oceanographic institutions of the country, this co-operation proving of mutual benefit.

That tidal data scientifically are of rather wide application is exemplified by the use of the tide observations made at Miami, Florida, and Cat Key, Bahamas. These tidal data are being used in a study of the variations in the Gulf Stream.

One very important by-product furnished by the primary

tide stations is the yearly values of sea-level. Changes in the relative elevations of land to sea have occurred in the past, and there is no reason for supposing that such changes are no longer occurring. That they are, as a rule, exceedingly slow we know; but it is only through these long-continued series of tide observations that we can gain any sure knowledge of the rate and direction of the changes going on.

Another purpose the primary tide stations are serving that needs emphasizing is their use in deriving mean values from short series of observations. It is obviously impractical to secure long series of observations at all places where precise data are desired. However, by means of simultaneous observations at properly chosen primary tide stations, the results derived from short series of observations at other places can be corrected to mean values.

During the past three years the harmonic analysis of tides, both for purposes of tidal studies and predictions, have been continued.

The tide tables for the year 1940 carry daily predictions for 106 principal ports and tidal constants and differences for over 4000 secondary stations.

The current tables, which are at the present time restricted to the coasts of the United States and island possessions, carry daily predictions for 29 waterways and current differences and constants for about 900 secondary ports.

H 6

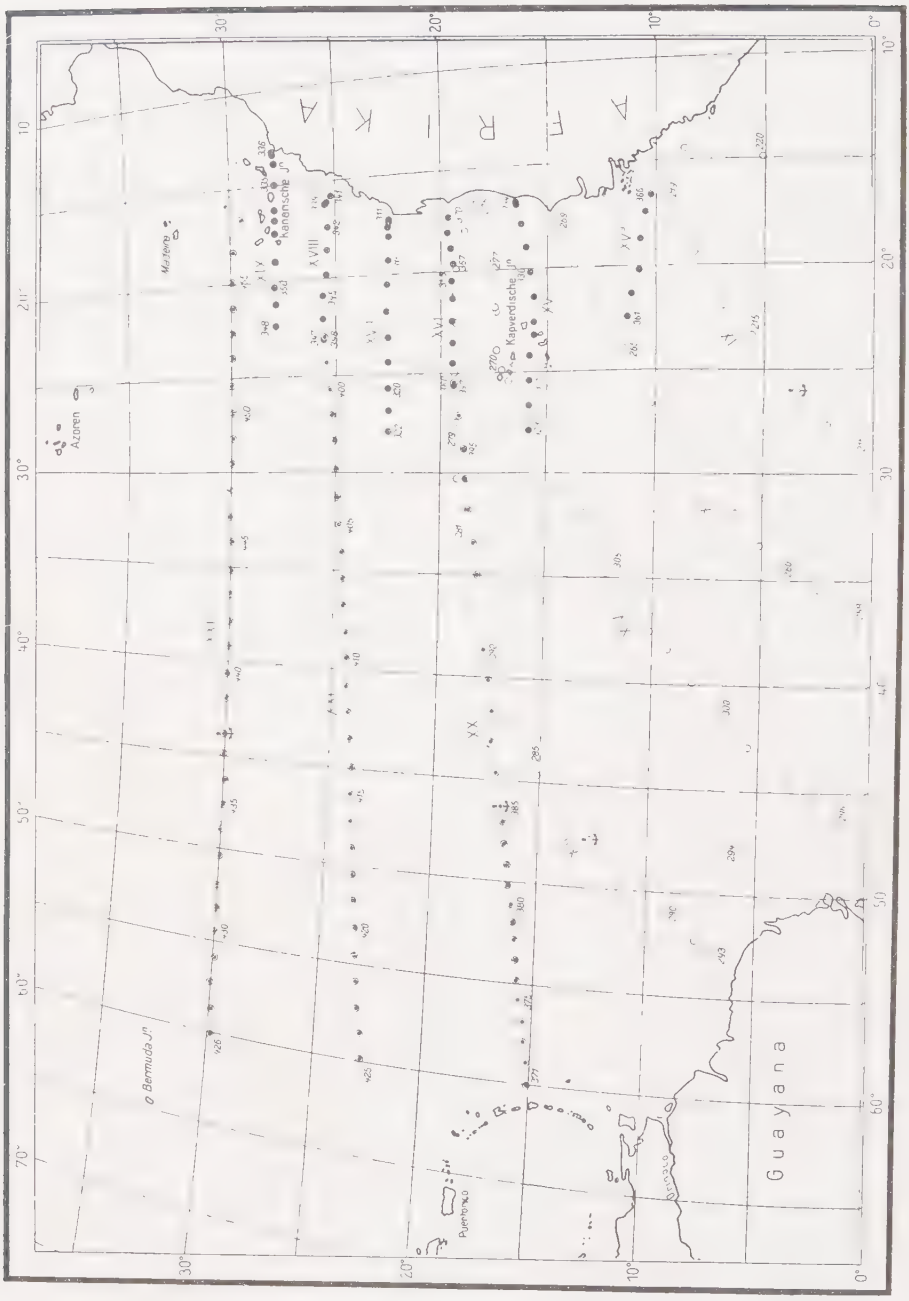
Die Ozeanographischen Arbeiten der Deutschen Nordatlantischen Expedition auf ihren zwei Teilfahrten Februar–Mai 1937 und Januar–Juli 1938

Von

A. DEFANT

Institut für Meereskunde, Berlin

Die Deutsche Atlantische Expedition des Forschungs- und Vermessungsschiffes "Meteor" 1925–27 hat den Südatlantischen Ozean von der Antarktis im Süden bis etwa 15° N Br. mit einem Netz von 310 ozeanographischen Stationen überdeckt, die, von der Oberfläche bis zum Meeresboden reichend, eine räumliche Erfassung des thermo-halinen Aufbaus der ganzen Wassermassen und ihrer Zirkulation, soweit es sich um stationäre Bewegungen handelt, gestatten. Die Ergebnisse dieser Expedition sind im "Meteor"-Werk, das bald seinem Abschluss entgegengeht, niedergelegt. Die Deutsche Kriegsmarine und die Deutsche Forschungsgemeinschaft haben sich 1937 entschlossen, diese systematische Aufnahme des Südatlantischen Ozeans nach Norden hin in einer "Nordatlantischen Expedition" fortzusetzen und auch den Teil von den Kapverdischen Inseln bis zu den Breiten Islands systematisch nach den auf der Südatlantischen Expedition erprobten modernen ozeanographischen Methoden aufzunehmen. Diese ozeanographische Expedition wird in einzelnen Teilfahrten von etwa 4- bis 6-monatlicher Dauer durchgeführt werden. Die ersten zwei Untersuchungsfahrten des "Meteor" fanden in der Zeit von Februar bis Mai 1937 und Januar bis Juli 1938 statt. Das Arbeitsgebiet der ersten Fahrt 1937 war das Meeresgebiet zwischen den Kapverdischen und Kanarischen Inseln, und in


AFRIKA
Guayana
Kanarische Jn
Kapverdische Jn
Azoren
Madeira
Bermuda Jn
Puerto Rico
Orinoco
XVIII
XVI
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XV
XIX
XXI

6 Profilen, die längs der Breitenkreise rund 600 sm von der Küste Afrikas nach Westen reichen, wurden 60 ozeanographische Stationen ausgeführt. Ausserdem wurden 6 Stationen zu 60-stündigen Stationen mit Serienmessungen mit einstündigem Intervall ausgebaut, um Material zum Studium kurzperiodischer Schwankungen der ozeanographischen Elemente bezw. internen Wellen zu bekommen. Die zweite Teilfahrt 1938 brachte erst die Fortsetzung der Arbeiten der Expedition 1925–27 nach Norden. Auf den drei west-östlichen Profilen im Meeresraum zwischen den Westindischen und den Kanarisch-Kapverdischen Inseln wurden 86 ozeanographische Stationen ausgeführt. Von diesen wurde jede zweite bis zum Meeresboden ausgedehnt, die anderen reichen bis 1500 m Tiefe. Drei der Stationen waren Ankerstationen auf 2220 bezw. 2850 m Wassertiefe und lieferten bei dreitägiger Dauer je 60 Wiederholungsserien in einstündigem Intervall und Strommessungen in 8 bezw. 10 Horizonten bis zur Tiefe von 800 bezw. 150 m. Im zweiten Abschnitt dieser Fahrt wurden ozeanographische Stationen der ersten Teilfahrt im Gebiete der Kanarischen-Kapverdischen Inseln wiederholt und auf Ankerstationen erfolgreich mit Hochseepegeln gearbeitet. *Abb.* 1 gibt die Lage der ozeanographischen Stationen auf diesen ersten zwei Teilfahrten der Nordatlantischen Expedition. Weitere Teilfahrten werden im Anschluss an das bisherige Arbeitsgebiet nach Norden hin durchgeführt werden. Es ist beabsichtigt, das ganze Beobachtungsmaterial dieser Teilfahrten und seine wissenschaftliche Verarbeitung in einem besonderen Werke laufend zu veröffentlichen.

H 7

A Study of the Variations in the Strength of the Gulf Stream, 1937-1939

By

C. O'D. ISELIN

Woods Hole Oceanographic Institution

Since June 1937 the Woods Hole Oceanographic Institution and the Bermuda Biological Station have been co-operating in a programme of observations designed to show up possible long-period changes in the strength of the Gulf Stream. This project originated at the suggestion of the Bermuda Oceanographic Committee of the Royal Society, a special grant having been obtained to make it possible for the Bermuda laboratory to participate. Since an outline of the aims and methods of this investigation has already been published (*Nature*, vol. 141, No. 3574), this report will be confined to a brief discussion of the progress to date.

If the Gulf Stream varies in strength from year to year, and if these variations can influence the fisheries or the climate, it is obviously desirable to discover some reliable method whereby, without too much expense, the fluctuations in the current can be observed over a considerable period of years. During the past two years various possibilities have been explored. Twelve complete hydrographic sections, crossing the current on the Montauk Point-Bermuda line, have been occupied. On at least four of these, strong eddies were met with on one or both sides of the current. Thus if the volume of flow is to be computed from the subsurface distribution of temperature and salinity, sufficient stations must be made on each occasion to demonstrate whether or not eddies are present.

How frequently should such observations be made and how great an error in the volume calculations can result from

short-period changes? Because the magnitude of the long-period trends is unknown, it is not yet possible to give a definite answer to either of these important questions. The available observations indicate that the current has an annual fluctuation amounting to at least 20 per cent. It reaches its maximum volume in May and June and its minimum in November and December. Because of this marked seasonal cycle, it may easily require as many as eight sections each year to show up variations having a longer trend. Our experience also indicates that in order to minimize the effect of internal waves the stations in each section should not be spaced farther than 20 miles apart. For these reasons, it takes at least eight days to complete each profile. On the whole, therefore, there appears to be little hope of reducing the time required for subsurface observations to a point where they can be conveniently secured by a research ship which has a number of other routine assignments. However, the sections so far occupied have greatly advanced our knowledge of the Gulf Stream, and indeed they are vital if we are to gain confidence in other, more indirect, methods.

Through the co-operation of the U.S. Coast and Geodetic Survey, tide gauges have been set up at Cat Cay, a small island directly across the Florida Straits from Miami, and at Bermuda. Data for fifteen months are now available from Cat Cay for comparison with the variations in mean sea-level at Miami. The instrument at Bermuda has been running for a somewhat shorter period. At the present time it seems likely that by studying the variations in mean sea-level at these stations in conjunction with the thermograph records of commercial ships crossing the Gulf Stream, a satisfactory record can be obtained of the long-period fluctuations of the current's volume. It is hoped that before long this method can supersede the much more expensive subsurface observations and thus permit the investigation to continue for a sufficient number of years to obtain significant results.

H 71

The Probable Significance of Temporary Migrations of Gulf Stream Water on the Atlantic Seaboard

By

H. B. HACHEY

Fisheries Research Board of Canada

The temporary migrations of Gulf Stream water are illustrated by the analysis of 161 thermograms, obtained during the period 1932–38 from instruments on vessels plying the Boston-Bermuda steamship route. The position of the northern limit of Gulf Stream waters, on this route, is shown to vary between latitude 36° 41′ N. and 40° 23′ N., respectively 275 and 60 miles from the New England coast. The more northerly positions of the northern limit of Gulf Stream waters are recorded in early winter and again in late summer, while the more southerly positions are recorded in spring and again in late autumn. Calculated average monthly positions indicate that the more southerly positions follow the equinoxes. This suggests that the position of the northern limit of Gulf Stream waters is related to current strength of the Gulf Stream. The most extensive migration of the northern limit of Gulf Stream water took place in 1937, while in 1934 the position of this northern limit was comparatively well to the south, and varied but little throughout the greater part of the year. On the basis of the theoretical considerations of Rossby, with respect to mutual adjustment of mass and velocity distributions in a current system, the calculated mean monthly positions of the northern limit of Gulf Stream waters are correlated with the average monthly differences in sea-level (reduced to normal atmospheric pressure) between Bermuda and Charleston, S.C. The correlation coefficient has a value of 0·36, which is twice its probable error. The results are therefore highly suggestive

that variations in the northerly limit of Gulf Stream waters reflect variations in the current strength of the Gulf Stream, decrease in the strength of the Gulf Stream being accompanied by northerly migrations of the northern limit of Gulf Stream water, and increase in strength accompanied by increased stability in the position of the northern limit of Gulf Stream waters. Hydrographic observations on the continental shelf of the Canadian Atlantic coast lend weight to the suggestions that increased speeds of the Gulf Stream, while causing a southward withdrawal of Gulf Stream waters on the surface, bring about a northward dispersal of Gulf Stream waters at the greater depths, resulting in a penetration of Atlantic waters over the shallower areas of the continental shelf. This southward withdrawal of the northern limit of Gulf Stream waters was most extensive in 1934, when a transgression of the nature elucidated by LeDanois was observed on the Scotian shelf, as well as in the Newfoundland area. The extensive northerly migrations of the northern limit of the Gulf Stream waters in 1937, which we suggest were associated with decreased Gulf Stream speeds, were accompanied by record-breaking surface temperature conditions in many areas on the Canadian Atlantic seaboard.

H 8

Fluctuations in the North Atlantic Drift-Current through the Faroe-Shetland Channel

By

J. B. TAIT

Fishery Board for Scotland, Marine Laboratory, Aberdeen

There is no question of the significance, in many and in various respects, of the seasonally and annually fluctuating amounts of warm oceanic water which finds continuous access to the seas of northern Europe through the Faroe-Shetland Channel and its immediate neighbourhood. The problem is to obtain more or less definite measure of this oceanic incursion, of its variations and fluctuations. Modern hydrodynamical methods, recently set out very clearly and usefully in a paper by Anton Jakhelln,* afford the means, provided the necessary observations of temperature and salinity are adequate, of making the desired measurements, in approximate degree at least.

The Fishery Board for Scotland, in its hydrographical work in connection with fisheries, has always looked upon the Faroe-Shetland Channel region as an essential part of its area of investigation, and in course of the present century many hydrographic sections have been completed across the Channel from Shetland to Faroe. In a few years this traverse has been made twice in the year, thus affording material for seasonal comparisons. Generally, a complete section has been worked only once in course of a year. When nearly the same calendar periods have been occupied, year to year comparisons, extremely useful from the point of view of annual fluctuations in the oceanic incursion, can be made.

The Shetland-Faroe section, or sections, however, have this

* Anton Jakhelln: "The Water Transport of Gradient Currents," Geofysiske Publikasjoner, Vol. XI, No. II, Oslo, 1936.

drawback. Already in the region between Shetland and Faroe, the oncoming Atlantic "stream" is evidently subject at certain times to considerable resistance, and sometimes dilution, by the waters of the East Icelandic Arctic current. In consequence of the former there is often a marked tendency towards lateral extension of the Atlantic water current and also towards eddy formations, thus obscuring, on a single section, the effective flow northwards to higher latitudes.

To obviate this difficulty and also, it was conceived, to obtain a better basis for the desired estimations, a new section, farther south, was instituted in 1927, and, as far as possible, this section has since been traversed within the same calendar period of each year. The section lies between the Butt of Lewis and the south-east corner of Faroe Bank, passing for some distance along the top of the Wyville Thomson Ridge and embracing also the deep waters on both sides of the Ridge. At the same time, from existing knowledge, the section was laid at right angles to the supposed mean path of the north-easterly directed Atlantic current over the Wyville Thomson Ridge. Calculations of the amounts of Atlantic water passing northwards over the Ridge in the late spring (end May) go to show that these amounts may vary from year to year by as much as 30 per cent. A 20 per cent. difference, such as has been shown by Helland-Hansen to apply to his Sogne Fjord section,* appears to be by no means uncommon.

* Bjorn Helland-Hansen: "The Sogne Fjord Section," James Johnstone Memorial Volume, University Press of Liverpool, Liverpool, 1934.

H 9

Observations on the Waters of the Arctic Ocean off the Alaskan Coast

By

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During the summers of 1937 and 1938, representatives of the Oceanographic Laboratories accompanied one of the authors (F. A. Z.), commanding officer of the United States Coast Guard Cutter *Northland*, on cruises in the Arctic Ocean.

Proceeding northward from Bering Strait into the Arctic and then north-eastward toward Point Barrow, currents approximating several knots flowed in general along the American coast-line and well off-shore. Between Bering Strait and Lat. 70° N., the temperature of the surface waters varied between 10·80° and $0{\cdot}0_2°$ (in the ice) in 1937, and between 11·98° and 5·83° in 1938, while the bottom waters varied between 10·3° and −0·81° in 1937, and between 11·70° and 3·84° in 1938. The surface chlorinity varied between 15·31 and 17·85 ‰; 16·56 and 17·83 ‰ in 1937 and 1938 respectively, disregarding the high temperature and low chlorinity near the outlets of large rivers in Kotzebue Sound.

From Point Lay north-eastwardly to Point Barrow, the surface temperature varied from 6·9° to 0·9°, and the bottom temperature varied from 6·8° to 1·1° in 1938. The chlorinity values over the same area were for the surface between 15·89 and 17·15 ‰, while for the bottom they were between 16·57 and 17·56 ‰ in 1938. During the summer of 1938 the ice was considerably farther north and well off-shore as compared to the conditions of 1937.

The plankton, which has not as yet been carefully studied, was not as copious as that found farther westward in the Arctic.

The waters were characterised by a phosphate content in the range of 0·27 to $1·72 \times 10^{-3}$ mg. at. for 1937 and 0·04 to $1·72 \times ^{-3}$ mg. at. for 1938. The dissolved oxygen content was of the order of 85 to 128 per cent. saturation for 1937 and 91 to 117 per cent. saturation for 1938. Throughout this entire area the water is exceedingly shallow, being approximately from 30 to 50 metres in depth.

The homogeneous waters of low temperature and high chlorinity (1·7° and 18·2 $^{\circ}/_{\circ\circ}$) off the northern Siberian coast evidently have their origin farther westward in the Arctic. That off the American coast originates in Bering Sea and exhibits the marked characteristics of Bering Sea water. This water has a higher temperature and a lower chlorinity and does not mix very thoroughly with the cooler and more con centrated waters of the western Arctic. The velocity of the general northerly currents is sometimes lowered or even the direction partially diverted by adverse wind conditions.

The numerous rivers emptying into Kotzebue Sound give it diluted and warmer waters during the summer, which join with the general northern moving stream on the east coast of the Arctic.

Interviews with the native hunters led to the conclusion that the general northerly movement of the waters is characteristic throughout the year.

H 10

Summary of Observations in Bering Sea and Bering Strait in 1937 and 1938

By

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En route to the Arctic Ocean in the summers of 1937 and 1938 on the U.S. Coast Guard Cutter *Northland*, several sections of stations were run in the eastern portion of Bering Sea. It was observed that there was a general northward movement of the waters from the Pacific into Bering Sea through the passes formed by the Aleutian Islands. Proceeding northward in Bering Sea, the chlorinities decreased from $18^{\circ}/_{\circ\circ}$ (32·5) to $16^{\circ}/_{\circ\circ}$ (28·9). The observations of 1937 were made much earlier in the season than in 1938. In the latter year the temperature increased with latitude from 7° to 12° C. South of 59° north latitude, there was considerable fluctuation in the temperatures of the surface waters which varied from 6° to 9°.

The discharge of great rivers like the Yukon and the Kuskokwim has a profound effect on the waters of the region. The dissolved oxygen in 1938 in the eastern portion of the sea varied from 89 to 105 per cent. saturation for the surface waters, and from 63 to 100 per cent. for the bottom waters.

The phosphate content for the surface waters in 1937 ranged from $0{\cdot}27 \times 10^{-3}$ mg. at. to $1{\cdot}86 \times 10^{-3}$ mg. at., while for the following year the range varied from $0{\cdot}12 \times 10^{-3}$ mg. at. to $0{\cdot}82 \times 10^{-3}$ mg. at. The bottom waters showed a phosphate content in 1937 of $0{\cdot}35 \times 10^{-3}$ mg. at. to $2{\cdot}45 \times 10^{-3}$ mg. at., while similar waters in 1938 showed a range from $0{\cdot}38 \times 10^{-3}$ mg. at. to $1{\cdot}74 \times 10^{-3}$ mg. at.

The entire eastern portion of Bering Sea is characterised by shallow waters varying in depth from a few metres to 150 metres

and averaging about 40 metres. In the central portion of the sea between St. Lawrence Island and St. Matthews Island a marked eddy exists. Another similar eddy is in evidence in the region north of St. Lawrence Island and south of King Island. While the tides of Bering Sea are small, nevertheless considerable tidal current was observed along the shores of St. Lawrence Island. However, between the western portion of St. Lawrence Island and the Asiatic coast, an exceedingly pronounced non-tidal current exists, described by the Eskimos as an "eternal" current, which moves in a northerly direction at all times of the year.

The waters of Bering Strait were studied. A very marked movement through the strait into the Arctic Ocean was observed, with the exception of the extreme western portion of the strait where a variable eddy seems to exist. The waters of the eastern portion of Bering Strait in 1938 showed an average temperature of 11·4° C. and a chlorinity of 17·1‰ (30·9). At the extreme western end of the strait a temperature of 2° C. was observed and a chlorinity of 18·2‰ (32·9). These colder and more concentrated waters were further characterised by higher values for phosphate and dissolved oxygen. This Siberian water was homogeneous and seemed to be characteristic for the area of the Siberian coast studied. This water also showed high values for phosphate and dissolved oxygen and a very abundant plankton population.

H 11

On Vertical Circulation in the Central North Pacific

By

R. REVELLE

Scripps Institution of Oceanography

Rossby and Montgomery * have shown that for a steady wind, and in the absence of advection, the depth of the homogeneous subsurface water layer of constant temperature and salinity is a function of the wind speed and the latitude. The relationship given by them may be expressed in the form

$$H = \frac{2{\cdot}67W}{\sin L} - {\cdot}0135W^2,$$

where H is the depth of the homogeneous layer in meters, W is wind speed in meters/sec., and L is latitude.

In the Central North Pacific between the Aleutian Islands and Hawaii, the average depth to the thermocline agrees with that computed from this equation when the mean wind speed over a three-month period is used. Regions in which the depth to the thermocline is greater or less than calculated may thus be considered as regions of convergence or divergence respectively. Observations in the summer of 1934 showed that three belts of convergence—namely, between latitude 49° to 47°, 37° to 34°, and 28° to 24°—existed in the region investigated and were separated by areas of divergence. These results are confirmed by calculations of divergence or convergence of the resultant surface currents for the quarterly period of June, July, and August as given on pilot charts. The calculations

* C. G. Rossby and R. B. Montgomery: "The Layer of Frictional Influence in Wind and Ocean Currents," Papers in Phys. Ocean. and Meteor., M.I.T. and Woods Hole Oceanographic Inst., Vol. III, p. 94, 1935.

are based on the equation of continuity under stationary conditions

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = -\frac{\partial w}{\partial z} = \text{Divergence},$$

where u, v, and w are the velocity components parallel to the x, y, and z axes respectively. If the divergence is assumed to be constant down to the depth, z, at the top of the thermocline, then the vertical velocity component, w, at that depth may be obtained.

In the region of the subtropical convergence, the rate of convergence equals 1×10^{-7} cm./sec./cm. and z equals about 45 meters, whence w equals $4{\cdot}5 \times 10^{-4}$ cm./sec. or about 140 meters per year.

Secondary maxima in the vertical distribution of oxygen are found at depths of 130 to 230 metres below the primary maximum in the photosynthetic zone, and it is suggested that these result from the sinking of annual layers of high-oxygen content.

The deduced vertical circulation is qualitatively in agreement with the distribution of temperature in the upper 400 meters. It is shown that the vertical movement may be interpreted in terms of the meridional circulation set up under the balance of forces between prevailing winds on the one hand and the climatic factors of heating and cooling, evaporation and precipitation on the other.

H 12

The Equatorial Water Masses of the Pacific

By

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Fleming, Moberg, and Revelle ("The Water Masses of the North Pacific," Assoc. Océanog. Phys., Procès-Verbaux, No. 2, pp. 106–7, 1937) have shown that temperature-salinity curves from the North Pacific can be classified into regional groups. That is, over large areas, individual stations have similar temperature-salinity curves. It was shown that all curves could be accounted for by mixing between two or more types of water. These "types" represent characteristic terminal or inflection points on the curves. Recent work has shown that instead of using individual points, it is preferable to define a characteristic water mass by part or all of the temperature-salinity curve. In this way the properties of the entire water column are considered rather than those of the water at individual points. If this definition is followed, a single water mass may be considered to exist in a region where the temperature-salinity curves are identical. This concept is very useful where lateral mixing, say, along σ_t surfaces, is taking place between water having different temperature-salinity relations.

Limiting temperature-salinity curves at temperatures less than 15°, with a spread of less than 0·10‰ in salinity, have been used to define the Equatorial Water Mass of the Pacific. These curves are approximately symmetrical to lines joining the following types of water: *B* (1·5° C. and 34·7‰) and *Eq* (5° C. and 34·55‰), and *Eq* to *S.Ö.S.* (14° C. and 35‰). *B* and *Eq* were defined by Fleming, Moberg, and Revelle and *S.Ö.S.* by Thomsen (Ann. d. Hydrog. Mar. Met., vol. 63, pp. 293–305, 1935).

Examination of all available data shows that this water mass extends westward from Central America for at least one-half the distance across the Pacific. The southern limit is at about 10° S. and the northern limit is at about 5° N. in the mid-Pacific, but extends much farther north near the coast of Central and North America.

To the north and south of the Equatorial Water Mass there are water masses possessing markedly different temperature-salinity characteristics. Within relatively narrow bands, transitional temperature-salinity curves are found which may be accounted for by assuming that lateral mixing takes place between the Equatorial Water Mass and those found in the tropical portions of the North and South Pacific.

At the salinity minimum (approximately 5° C. and 34·55°/$_{\circ\circ}$) the Equatorial Water Mass has a higher salinity than the minima of the bordering water masses. This implies that vertical mixing must be an important factor in the formation of the water mass in the equatorial zone.

H 13

The California Current in 1937, 1938 and 1939

By

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Recently the Scripps Institution of Oceanography has carried out repeated observations in a shoreward portion of the California Current. Within an area from 31° N. to 35° N., and extending 150 miles to sea, a network of over 30 stations was established. Three cruises were made in the spring and early summer of 1937 by the *Bluefin*. Temperature observations, and salinity and oxygen determinations were made and the currents associated with the distribution of density were computed. At two-month intervals during 1938 the *E. W. Scripps* made six cruises covering the same area and enlarged the programme to include phytoplankton and zooplankton collections, and on three cruises, phosphate determinations. During the interval May to July 1939 the *E. W. Scripps* extended the work to cover an area from 28° N. to 45° N. and seaward for approximately 350 miles.

The 1937 and 1938 investigations showed the following general features in the flow off Southern California. Between the California Current and the coast there is commonly a flow to the north termed the California Counter Current. The Counter Current is most conspicuous during the fall and winter months when it extends northward for great distances along the coast both at and below the surface. During the spring, when the north-west winds are strongest, the Counter Current may disappear entirely at the surface, and at the same time upwelling along the coast results in an increased transport to the south. The effect of upwelling was not apparent at depths greater than 200 metres, which is apparently the lower limit of

influence of local climatic agencies. Below 200 meters the Counter Current persisted, as evident from dynamic computations and from the characteristic temperature-salinity relationship and dissolved oxygen content of the water.

The properties of the Counter Current water are altered as the water flows north owing to large scale lateral mixing which is maintained by eddies of diameter up to 50 km. The modifications are very conspicuous owing to the marked difference in the temperature-salinity relationship and dissolved oxygen content of the water of the Counter Current and that of the California Current.

From the alteration of oxygen content, the consumption of oxygen in a water column of 1 m^2 cross-section reaching from 50 to 700 m. was, in 1937, found to lie between the limits 1·1 and 2·2 litres per day.

H 14

The Gulf of California

By

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In February and March 1939 the Scripps Institution of Oceanography undertook a general oceanographical exploration of the Gulf of California. The research vessel, the *E. W. Scripps*, worked in the Gulf from 13th February to 19th March, during which time 53 oceanographic stations were occupied, located along nine lines across the Gulf with three to ten stations on each line. Soundings with fathometer were made for nearly every mile, and at the stations temperatures and water samples were obtained from standard depths, bottom samples were procured, samples for quantitative determinations of phytoplankton were collected from seven different depths, and vertical net hauls for zooplankton were made. The present report will deal briefly with some of the outstanding results as to the character of the currents in the Gulf during the time of the cruise.

Hydrographically, the Gulf can be divided into two portions, an outer portion which is more or less funnel-shaped with increasing depth towards the outer end, and an inner portion which, in part, is very shallow but also shows some deep depressions, and which is separated from the outer portion by a ridge running approximately south-south-west from Tiburon Island.

In the outer portion the deep water is of the same character as the deep water of the adjacent part of the Pacific. It is characterised by practically no oxygen between 200 and 800 meters and by a salinity minimum of 34·50 to 34·55$^{\circ}/_{\circ\circ}$ at a depth of approximately 800 meters. From the character of the water and from dynamic computations it appears that an

intermittent exchange of water takes place between the Gulf and the Pacific Ocean, the inflow mainly following the eastern side of the Gulf, and the outflow, the western side. In the surface layers a somewhat similar system of currents appeared to be present, but was there further complicated by intermittent upwelling along the eastern coast of the Gulf due to the northerly winds.

The waters in the deeper parts of the northern portion show that these deeper parts have the character of basins. Vertical circulation due to the winter cooling and excessive evaporation must reach to considerable depths, but inflow over the sill to the south of Tiburon Island must also contribute to the formation of the waters in the basins.

H 15

Die Grenzen der Ozeane und Meere

Von

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Für viele Fragen der Ozeanographie ist es erforderlich, die genauen Grenzen der Ozeane und Meere an der *Oberfläche* des Weltmeeres und die speziellen geographischen Benennungen, die nach den herrschenden wissenschaftlichen Auffassungen diesen Teilgebieten des Weltmeeres zukommen, zu kennen. Die Angaben über diesen Gegenstand sind in der Literatur stark zerstreut; eine zusammenfassende, allen wissenschaftlichen Ansprüchen genügende Veröffentlichung, welche eine rasche Unterrichtung gestattet, lag bisher nicht vor. Für gewisse praktische Zwecke des Hydrographischen Dienstes hat zwar das Internationale Hydrographische Bureau in Monaco auf Grund einer Rundfrage die Spezialpublikation No. 23 "Limits of Oceans and seas" (1. Auflage 1928; 2. Auflage 1937) herausgegeben; sie soll dazu dienen, den Hydrographischen Ämtern ein Einteilungsprinzip für die Einordnung der Segelanweisungen, Nachrichten für Seefahrer usw. an die Hand zu geben, und auf diese Weise sicherstellen, dass alle nautischen Publikationen, die auf dem Titel den Namen eines bestimmten Ozeans oder Meeres tragen, sich auf dasselbe Areal beziehen. Im Vorwort zur zweiten Auflage dieser nautischen Veröffentlichung wird nunmehr die Hoffnung ausgesprochen, dass die vorgeschlagenen Grenzen auch für die Wissenschaft annehmbar seien, und in einem Rundschreiben an die Mitglieder des in Edinburgh 1936 eingesetzten internationalen "Committee on the criteria and nomenclature of the major divisions of the ocean bottom" wird die Stellungnahme der internationalen Ozeanographie zu diesen nach praktischen Gesichtspunkten gezogenen schematischen Grenzen erbeten.

Bei einer sorgfältigen Prüfung dieser Publikation des Internationalen Hydrographischen Bureaus und der ihr beigegebenen Übersichtskarte (in Merkator-Projektion) habe ich festgestellt, dass zwar die Namengebung—bis auf einige Ausnahmen—mit den auch in der deutschen Wissenschaft üblichen Bezeichnungen der Ozeane und Meere übereinstimmt, dass aber die vorgeschlagenen Grenzen vielfach mit den von der internationalen Wissenschaft seit langem anerkannten Grundsätzen unvereinbar sind.

Ich erlaube mir, hiermit eine neue diesen Gegenstand behandelnde Veröffentlichung vorzulegen, welche auf einer Zusammenarbeit mit dem Deutschen Hydrographischen Dienst beruht und kürzlich als Beiheft zu den "Annalen der Hydrographie und maritimen Meteorologie" erschienen ist. In dieser wissenschaftlichen Veröffentlichung werden ausführlich die Grundsätze entwickelt, die sich in der internationalen Wissenschaft bezüglich der Begrenzung und Benennung der Ozeane und Meere ergeben haben und heute vorherrschen, und im Anhang und in einer flächentreuen Karte sind im einzelnen die genauen, wesentlich nach morphologischen Gesichtspunkten fixierten Grenzen der Teilgebiete übersichtlich zusammengestellt. Bezüglich der Übersetzung der deutschen Benennungen in das Englische wird auf die Veröffentlichung des Internationalen Hydrographischen Bureaus verwiesen.

H 17·1

Horizontal Oscillations of Bay Water induced by Tidal Currents

By

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In a small bay facing the straits where vigorous tidal currents prevail, we find usually a counter current. This is, of course, ascribed to the motion of bay water induced by the tidal currents running outside the bay, and the motion is repeated with a period identical with that of the tides. In the Ōsaka-wan the isobath of 20 *m* divides the sea into two parts, the one deeper than 20 *m* and attaining depths of 60 ~ 70 *m*, occupies the western half of Ōsaka-wan and is like a canal with a strong tidal current flowing along it. The other region is mostly very shallow and the motion of water in it can be regarded as induced by the motion in the former region. These phenomena can be explained as the horizontal transfer of momentum of water motion by means of eddy viscosity. Such an idea was adopted by Defant (1), and Richardson and Proctor (2) for atmospheric motion, and was recently applied to ocean currents by Rossby (3). In the investigation now described, such phenomena were treated theoretically, and the equations solved by a numerical method, formulated by modifying L. Collatz's method of numerical integration of linear differential equations (4).

Consider a bay of constant depth having a length H and width $2H$. The motion outside the bay is restricted to a direction perpendicular to the axis of the bay. The tidal currents are assumed periodic and everywhere uniform outside the bay.

Take the axis of x along the mouth of the bay and that of y perpendicular to it. The equations of motion are *

$$\left.\begin{aligned} 2\omega \sin\phi\, v - \frac{1}{\rho}\frac{\partial p}{\partial x} &= \frac{\partial u}{\partial t} - \frac{\kappa}{\rho}\Delta^2 u \\ -2\omega \sin\phi\, u - \frac{1}{\rho}\frac{\partial p}{\partial y} &= \frac{v}{\partial t} - \frac{\kappa}{\rho}\Delta^2 v \end{aligned}\right\} \tag{1}$$

where p is the pressure, u and v the velocity components in the x- and y- directions, κ and ρ the coefficient of horizontal eddy viscosity and density of water, t the time, ω the angular velocity of the earth's rotation and ϕ the geographical latitude. Next we assume that the motion is purely two dimensional and that no vertical motion is present. Under this supposition, we have

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0. \tag{2}$$

Introducing the stream function ψ such that

$$u = \frac{\partial \psi}{\partial y}, \qquad v = -\frac{\partial \psi}{dx}, \tag{3}$$

we see that (2) is at once satisfied. If we eliminate p from the two equations in (1) and use ψ instead of u and v, we have

$$\frac{\partial}{\partial t}\Delta^2\psi - \frac{\kappa}{\rho}\Delta^4\psi = 0, \tag{4}$$

where

$$\Delta^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}, \qquad \Delta^4 = \frac{\partial^4}{\partial x^4} + 2\frac{\partial^4}{\partial x^2 \partial y^2} + \frac{\partial^4}{\partial y^4}.$$

To solve (4) put

$$\psi = \psi_1(x, y) \cos\sigma t + \psi_2(x, y) \sin\sigma t, \tag{5}$$

where ψ_1 and ψ_2 are functions of x and y, and $2\pi/\sigma$ is the period of tidal current outside the bay. Substituting in (4) and equating to zero the coefficients of $\cos\sigma t$ and $\sin\sigma t$, we have

$$\Delta^4\psi_1 + 2q^2\Delta^2\psi_2 = 0, \qquad \Delta^4\psi_2 - 2q^2\Delta^2\psi_1 = 0, \tag{6}$$

* Squares and products of velocity components were neglected as small.

where

$$q = +\sqrt{\frac{H^2\rho\sigma}{2\kappa}}.$$

The conditions to be satisfied at the three boundaries are that no slip of water is experienced along the shore.

The equations (6) were solved numerically; and we calculated the functions ψ_1 and ψ_2 against several values of q. When $q=0$ there is no phase-lag between the currents outside and inside of the bay. As q increases such a lag increases gradually and reaches as large as 90° in the limit when $q \to \infty$. The velocity inside the bay decreases with increasing q, till no motion is observed inside the bay if $q \to \infty$.

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(4) For details of the integration method, refer to a paper by the author in Mem. I. Marine Obs., Kobe. As to Collatz's method, read L. Collatz, "Das Differenzenverfahren mit höherer Approximation für lineare Differentialgleichungen," Schrift. Math. Seminars Inst. angew. Math. Univ. Berlin, B. 3, Heft 1 (1935); "Über das Differenzenverfahren bei Anfangswertproblemen partieller Differentialgleichungen," Zeitsch. angew. Math. Mech., B. 16, S. 239 (1936).

H 18

Sea-Level and Surface Temperatures along the Coast of California

By

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(Based upon "Variations in Sea-Level on the Pacific Coast of United States," Journal of Marine Research, Vol. 2, No. 1, June 1939.)

The monthly mean sea-levels obtained from the Coast and Geodetic Survey's permanent tide gauge located at San Diego, La Jolla and Los Angeles harbour show corresponding annual cycles with a high in September and October, and a low interval in April and May. The average amplitude of seasonal fluctuations in monthly sea-level at these stations is about six inches (15 cm.).

From examination of records of sea-level at La Jolla, and the extrapolated values of dynamic topography from nine oceanographic surveys, it is concluded that nearly all the variations in sea-level can be accounted for by variations in the density of the water above the 500-decibar surface. Most of this change in density occurs above the 75-decibar surface.

Since seasonal temperature changes in the upper water layer have a far greater effect upon density variations than do salinity fluctuations, there exists a high correlation between sea-level and surface temperature. This correlation is significant for each week throughout the year, and is especially high for annual periods.

The observed changes in the density of the coastal waters are too great to be caused by local effects of solar heating and evaporation, and must be attributed to the circulation. For example, a warm subsurface current usually extends to the

region near San Francisco in winter, reducing the average density of the vertical column of water, which results in a high sea-level during this period. In Southern California the sea-level varies with the amount of southerly flow near the coast. An increased southerly current lowers the sea-level. This holds true not only from weekly periods and seasonal cycles, but it can also be assumed that year to year variation in sea-level are representative of the extent of the southerly transport of cold water along the coast.

Deviations of long duration affect the sea-level in large areas; variations of short duration affect a smaller area. Annual deviations are usually felt as far north as Seattle, while monthly deviations are not always recorded as far north as San Francisco. The fluctuations of the currents appear to be associated with widespread variations in atmospheric conditions. This conclusion is substantiated by the fact that variations in winter rainfall at La Jolla shows a high correlation with the variations in the annual sea-level on the coast of Southern California.

H 19

Secular Variation of the Surface-Temperature of the Sea along the Norwegian Coast

By

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About seventy years ago ten meteorological stations along the Norwegian coast were instructed to measure once daily the surface temperature of the sea. These observations have continued with as few changes as possible, and we now have six stations, all at lighthouses, with fairly homogeneous series of surface-temperature observations from 1870. These stations are well distributed along the Norwegian coast and they all lie near the open sea. The measurements are taken in the boat harbour where water samples can be procured even in stormy weather. The instructions for the observations have not been changed since 1870.

Mean values of the surface temperature for the different months and for the year have been calculated and have been published in "Jahrbuch des Norwegischen Meteorologischen Instituts" since 1870.

For the study of secular variations we have computed consecutive average values for thirty years, namely, for the periods 1870–99, 1871–1900, 1872–1901 . . . 1909–38. These average values were calculated for the different months, for the different seasons and for the year. By this method, short periodic variations are eliminated and eventual secular variations are seen clearly. Especially conspicuous are the secular variations when the averages are represented graphically in form of curves.

In northern Norway the mean annual sea-temperature falls

until the period (1888–1917), while the fall continues until (1897–1916) in southern Norway. Then a rise commences, amounting to 0°·7 to 1°·0 C. in the north and to 0°·2 to 0°·4 in the south of the country. This rise still continues.

The rise is especially great in the summer and amounts to 0°·4 to 1°·1. In the winter it is smaller (0°·2 to 0°·6), but begins even before the observations were started.

The surface temperature of the sea thus shows a secular variation of the same magnitude as the secular variation of the air temperature in Norway. But there are evident differences.

The rise of the air temperature in winter is, *e.g.*, especially strong, up to 2° C., and it is relatively small in the summer, while for the sea-surface we have found the greatest rise of temperature in the summer.

The influence of the direct contact between the sea and the air is thus not strong enough to produce parallel secular variation. But the mutual influence of the sea and the atmosphere is not limited to these contact transfers. The temperature distribution of the sea affects, *e.g.*, the pressure distribution in the atmosphere (formation and development of cyclones).

It is of special interest to study the variation near the great atmospheric action centre of Iceland, where three stations with observations of surface temperatures (Stykkesholm, Papey and Vestmannøy) are at our disposal.

We find here a much greater rise of the surface temperature in the winter (0°·8 to 1°·2) than along the Norwegian coast, and the rise of the mean annual surface temperature is also greater.

At the same time the number of days with sea-ice in the waters of Iceland has diminished considerably. Information is here available from about 1780. The number of days with sea-ice has been computed for consecutive thirty-year periods.

There is—

(1) a fall until the period (1836–65);

(2) a rise from the period (1836–65) to the period (1862–93);

(3) a great fall from the period (1862–93).

This considerable fall in the number of days with sea-ice verifies in a good way the rise of the surface-temperature during the winter that we have found at the three Icelandic stations.

It is probable that such a rise of the sea-temperature will induce an increased activity of cyclones and that this again is the cause of the considerable increase of the air-temperature in winter in Norway. In this way we see a connection between the variations we have found. Further studies are, however, necessary before certain conclusions can be drawn.

H 20

Do Permanent Deep-Sea Currents Exist?

By

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Since the first discovery of the low temperature of the deep water in equatorial areas, it has been assumed that deep and bottom currents exist carrying cold water from high latitudes. At some lesser depths a return flow must take place. In the case of the Atlantic Ocean Wüst has deduced, on the basis of temperature, salinity and oxygen distribution, a complete picture of the meridional circulation. It has long been evident that processes of mixing must contribute to changes in the character of the waters, but so far only the effect of vertical mixing has been considered. In the case of the South Atlantic Ocean Defant has shown that the distribution of temperature and salinity can be fully explained if one assumes the existence of permanent deep-sea currents and of vertical mixing.

The effect of lateral mixing so far has been disregarded because the lateral gradients of temperature, salinity, etcetera, are so small that the coefficients of lateral mixing would have to be a million times greater than those of horizontal, in order to produce a noticeable effect. Rossby has recently pointed out that lateral mixing may be very effective in the ocean, and he has shown that non-permanent wind systems may give rise to the non-permanent currents at all depths between the surface and the bottom. Distributions of temperature and salinity studied by Parr off the Grand Banks of Newfoundland and by Sverdrup and Fleming off the coast of southern California strongly support the view that lateral mixing is of importance in the ocean. From the data off the coast of California it was found that the observed distribution of temperature and salinity could be

explained by introducing a coefficient of lateral mixing of the order of 10^6.

These results bring up the question whether it is necessary to assume the existence of permanent deep-sea currents in order to explain the observed distribution of temperature and salinity, or whether these distributions can be explained as the combined effect of lateral and vertical mixing. A study of conditions in the South Atlantic Ocean indicates that the latter alternative is possible, provided that the coefficient of lateral mixing is approximately a million times greater than that of the vertical.

H 21

Consideration of the Depth of the Motionless Surface near the Grand Banks of Newfoundland

By

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U.S. Coast Guard

The intelligent interpretation of dynamic calculations and the determination of absolute current directions and velocities therefrom by the use of the Bjerknes formulæ, depend upon a knowledge of the location and shape of a motionless reference surface. The arbitrary selection of isobaric surfaces for reference in the past has been the resort to an approximation found useful in the absence of more definite knowledge regarding the true location and shape of such a motionless surface or surfaces. In recent years various oceanographers have proposed various non-spheroidal reference surfaces such as the oxygen-minimum layer, and a surface approximating an isentrope of constant vertical stability. The state of our knowledge has not yet reached the point where we can define a surface which is universally applicable. Until such a stage of development is reached each unique region must be dealt with individually, and the several particular solutions may help in ultimately laying bare the general solution.

In the southern part of the Labrador Sea, where of course the oxygen-minimum surface cannot be used since it is not present, an isobaric surface was selected by statistical and graphical means on the assumption that the layer in which the velocity was most nearly uniform would also be the layer in which the velocity would be most nearly zero. Similar methods were used on data from an adjacent area to the south, east of

the Grand Banks. Various bits of contributory evidence, including patterns of flow, bottom temperatures, T-S diagrams, deep-level isentropic temperatures, and a water-transport balance are presented, all affirming the approximation to zero velocity in the surfaces selected.

H 23

Characteristics of the Waters in Sections from Dutch Harbour, Alaska, to the Strait of Juan de Fuca, and from the Strait of Juan de Fuca to Hawaii

By

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In the latter part of July and the first part of August 1935, two sections were run across the North Pacific by the U.S.S. *Oglala*, namely, from Lat. 50° 38′ N., Long. 172° 45′ W., to Lat. 48° 10′ N., Long. 125° 40′ W., and from the latter to Lat. 21° 57′ N., Long. 157° 12′ W. The time allotted for oceanographic work made it necessary to place the stations 150 miles apart. Temperatures and chlorinity samples were taken to depths of 2500 to 3000 meters and represent the first two complete sections in these regions.

The temperature of the surface water in the northern section showed a gradual increase from Unimak Pass to the eastward to approximately Lat. 50° N. and Long. 137° W. For the remainder of the section the increase was much more rapid, until the last station at the mouth of the Strait of Juan de Fuca, which showed a decrease. As the Strait of Juan de Fuca was approached, marked evidence of upwelling was observed. Proceeding from the Strait of Juan de Fuca to Hawaii, except for evidence of upwelling at the first station (Lat. 48° 10′ N., Long. 125° 40′ W.), there was a very gradual increase in temperature to Lat. 42°, Long. 136°, when noticeable temperature increases were observed. This increase was equivalent to about 1° C. per 100 miles sailing in a south-westward direction.

Chlorinity values approximately 18°/₀₀ Cl (32·5°/₀₀ S) were obtained for the surface waters throughout the Dutch Harbour-Juan de Fuca section. The isochlors show an upward trend on the eastern coast of the Pacific. In the western end of the section there is a marked drop of the 19 and 19·1 isochlors (34·5°/₀₀ S).

For the Juan de Fuca-Hawaii section the isochlors of the surface strata are very much the same as those for the previous section for about 500 miles south-westward. However, the isochlors for the deeper waters over the same area show a sinking near the eastern shore rather than a rise. Between Lat. 37° N., Long. 142° W., and Lat. 34° N., Long. 145° W., there is a marked uniformity in the chlorinity of the waters to a depth of 500 meters. South-west of this area there is a marked increase in concentration when chlorinities of 19·6°/₀₀ (35·5°/₀₀ S) are reached off the Hawaiian Islands.

Plotting the temperature-salinity curves across the Juan de Fuca-Hawaii section shows the very marked changes in the characteristics of the water for the strata above 500 metres, and at the same time the comparative homogeneity of the abysmal waters. Similar curves for the Aleutian Island-Juan de Fuca section demonstrate the very homogeneous nature of the waters of the eight western stations of this section. The other four stations give temperature-salinity curves that are analogous to those obtained in the eastern part of the Juan de Fuca-Hawaii section.

The latter part of September 1938, on a cruise from the Aleutian Islands to Seattle, the U.S. Coast Guard Cutter *Northland* covered nearly the same course as the *Ogiala* in 1935. Time did not permit the taking of depth samples, but surface observations were made hourly for temperature, chlorinity, phosphate, and nitrite. The same general trend of the characteristics of the waters was observed.

From the temperature and chlorinity data obtained in the sections, ocean currents were calculated. From these calculations it is evident that the general current 100–150 miles south of the Aleutian Islands flows in an easterly direction. Further eastward in the Gulf of Alaska the current has a slight northerly component, indicating the probable existence of a

large cyclonic eddy. On the Juan de Fuca-Hawaii section the current vectors indicate the existence of large anticyclonic eddies centered about Lat. 46° 40′ N., Long. 128° 40′ W., and Lat. 42° N., Long. 136° 30′ W. There is very little movement of the surface waters over the area between Lat. 32° N., Long. 148° W., and Lat. 27° N., Long. 153° W.

H 24

Tidal Cycle Variations in the Composition of Sea Water

By

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The composition of inshore ocean water varies not only with season, depth and location, but also with tide. Five stations in or near the waters of the San Juan Islands were selected to study such variations. On each location the M.S. *Catalyst* was anchored and the change in composition of the water followed throughout a 24- or 48-hour period. Four of the stations permitted sampling down to 100 meters and one to 20 meters. The temperature, chlorinity, density, dissolved oxygen, silicate, phosphate, nitrite, hydrogen-ion concentration, alkalinity, titration alkalinity, borate, and fluoride were determined for each water sample. Certain of these results have been plotted; a correlation and analysis of the variations has been attempted.

H 25

An Oceanographic Thermo-Sounder

By

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The development of physical oceanography has brought, during the later years, an increase of the claims of the closeness of observations, both in space and in time. In order to meet these claims, more rapid and convenient methods of observation are required, and one attempt has been made by the construction of this thermo-sounder, an instrument for the automatical registration of the vertical distribution of temperature during full speed lowering to any desired depth. In the construction of the apparatus I have had valuable help from ing. Odd Dahl of the Chr. Michelsen Institute in Bergen.

The principle is very simple; the thermal expansion of a brass string gives a micro-registration on a glass plate, covered with soot, while the depth is determined by a propeller.

A hard brass string, 0·5 mm. thick and about 75 cm. long, is mounted on a frame of invar steel, at one end by means of an adjusting screw and at the other by a stiff steel spring (0·30 mm. thick and about 14 mm. long), which keeps the brass string straight. To the end of the steel spring is also attached a fairly stiff arm, of thin brass plate, about 15 cm. long, carrying a sharp pen of platin-iridium. A temperature change of 1° C. of the string corresponds to about 0·15 mm. on the temperature scale. As the record may be read, under a microscope, to the nearest 0·01 mm., one can thus determine the temperature variations down to less than 0·1° C. A fixed pen gives a zero line on the glass plate. Theory and practical

experiments show that the temperature scale will be nearly exactly linear.

It is, of course, very important that the string adopts the temperature of the surrounding water sufficiently rapidly. This has been proved by simple experiments in the laboratory and by direct tests in the sea, controlling the results by measurements with reversing thermometers.

H 26

Rapid-Measuring Hydrographic Instruments

By

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In connection with an attempt to obtain a representation and explanation of some impermanent current systems in the ocean (eddies in the neighbourhood of the Gulf Stream), two simple instruments have been developed. These instruments have been designed to satisfy a need for new instrumental technique in the form of rapid measuring instruments which will provide observations approximating more closely to synchronous conditions.

The two instruments are, first, the Bathythermograph, for obtaining a continuous record of temperature against depth (pressure); while the second instrument, which may be described as a pressure operated multiple sea sampler, is for collecting samples at various predetermined depths (six in number in the case of the present model) for subsequent determinations of salinity or oxygen. Both instruments are small and light and may be used on a hand-line. In view of the fact that a pressure element determines the depth in both, wire angle difficulties are eliminated.

Tests and comparisons of the instruments with the standard methods have been made. The results indicate a great deal of "fine structure," which is not brought out by the usual water-bottle technique. It is hoped that the further development of such instrumental methods will facilitate the distribution of such equipment to a relatively large number of vessels (fishing boats, etc.), so that a network for taking synchronous observations may be eventually set up. Such a development seems essential for the ultimate understanding of the more transitory ocean current systems.

H 27

The Spectral Distribution and Total Intensity of Daylight in the Waters of the Pacific North-West

By

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The interest of physical oceanographers and biologists in submarine light measurements has resulted in observations on the relative intensities of transmitted and scattered light beneath the surface of water bodies. These relative intensities have been determined principally by the use of various types of rectifier cells. These cells are sensitive over a range of wave-lengths extending beyond both the short and long wave-length limits of the visible spectrum. While the maximum response of such cells is in the region of the maximum spectral sensitivity of the eye, their relative spectral sensitivities do not coincide with the spectral sensitivity curve of the eye and hence cannot yield illumination intensities as evaluated by the eye. Also, since the electric current produced by rectifier cells is not always a linear function of the illumination, extinction coefficients computed from current measurements are affected by this departure from linearity.

Observations were made in the waters of the Pacific North-West by means of a submarine photometer employing photronic cells. Each of the cells was provided with a filter, such that the combination of cell and filter gave a spectral response curve which very nearly coincided with the average spectral sensitivity curve of the eye. Deviations between the two curves were less than the deviations of individual eyes from the average eye curve. In order to account for departure from linearity, the photometer was calibrated and checked from time to time during the observations. As unequal variations of the intensity of

different components of the surface radiation were observed, a separate correction was made for each variation rather than for the variations in the integrated response of a surface photometer. It was thus possible to measure the intensity of the total radiation and of selected spectral bands in *visual illumination units*, i.e. *lux* or *foot-candles*. The photometer was so constructed that nearly simultaneous observations could be made of the total visual intensity as well as of the visual intensity of different spectral components.

The regions selected for observations included ocean water off the continental shelf, straits connecting ocean and inshore waters, sounds, bays, and harbours.

H 28

Vertical and Off-Shore Dispersion of Silt from the Southern California Shore

By

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In semi-arid regions such as that of Southern California there is an occasional period of heavy rains causing an excessive run off accompanied by soil erosion. This results in a concentration of silt at river mouths. This silt then quickly disperses seaward. Accordingly, it is of interest to investigate the quantitative distribution of the silt by formulating various problems simple enough to be solved and involving appropriate boundary conditions and assumptions. At the suggestion of Dr. Roger Revelle of the Scripps Institution it is assumed that the silt settles at a constant rate of ·02 cm. per second, and diffuses both horizontally and vertically because of turbulence which is much greater in a horizontal than in a vertical direction.

In order to obtain a suitable series of type solutions, for comparison with observations that may be made on silt concentration, the diffusion equation

$$\frac{\partial s}{\partial t} = a^2\frac{\partial^2 s}{\partial x^2} + b^2\frac{\partial^2 s}{\partial y^2} - V\frac{\partial s}{\partial y}$$

is solved, subject to the following different boundary conditions:

First, assume an instantaneous point source and zero concentration except at the source.

Second, assume a continuous point source.

Third, assume a continuous line source, parallel to the coast.

Fourth, determine the effect of the size of the volume (assumed to be rectangular) originally assumed to contain a concentration of silt.

A preliminary series of surface observations at a series of distances from shore agreed best with the continuous point source.

H 29

Radium Content of Ocean Bottom Samples in the Pacific, Bering Sea, and the Arctic

By

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More than one hundred bottom and core samples, taken along the Pacific Ocean, Bering Sea, and Arctic coasts of the northern part of the United States, Canada, and Alaska, have been analysed for their radium content. Some of the samples were collected in Bering Sea along the coast of Siberia and some from the inside waterways of Alaska. All of the bottom surface samples were collected by means of a clam shell sampler, while the core samples, which were from relatively shallow waters, were obtained by driving a core sampler tube into the ocean bottom. The core samples, varying from 14 centimeters to 17 centimeters, were comparable in length with those obtained by H. Pettersson, but were very much shorter than those obtained by C. S. Piggott.

The method of analysis consisted in the measurement of the ionisation produced by the radon in equilibrium with the radium in the sample. The apparatus was essentially that developed and used by R. D. Evans.

Each sample was dried, ground, weighed, baked, and sealed in a glass container for one month, after which the radon was removed from the sample in a vacuum electric furnace and washed into a differential ionisation chamber by means of radon-free nitrogen. A string electrometer was connected in such a manner that it measured the difference between the ionisation in the two chambers. The background ionisation was measured before each radon determination.

The average radium content of the samples was of the order

10^{-12} grams of radium per gram of dried material. This value is comparable to that of ordinary igneous rock. However, samples from the region of the Queen Charlotte Islands, Vancouver Island, and the San Juan Archipelago had a lower radium content, while those taken in Portland Canal, Taku Glacier Inlet, Lynn Canal, and St. Lawrence Bay had a much higher radium content. All of these latter waterways are fed by glaciers. One sample, taken at the edge of the continental shelf, contained $2{\cdot}3 \cdot 10^{-12}$ grams of radium per gram of dried sample.

The radium content of the cores showed no systematic variation with depth with the exception of one core, taken at the mouth of St. Lawrence Bay, which showed a definite decrease of radium with depth.

H 30

The Distribution of Organic Carbon and Nitrogen in Sediments from the Arabian Sea

By

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and

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The amount of organic carbon and nitrogen have been determined on bottom sediments from 44 Arabian Sea Stations. In addition estimations have been done on the lower portions of 16 cores. For the determination of organic carbon, both wet and dry combustion methods were tried, but the results obtained by the combustion method were all slightly lower than those from the wet method, and this was traced to carbon dioxide retained by the lead chromate or copper oxide. Consequently it was decided that the wet method (a mixture of chromic acid and phosphoric acid was used as an oxidizing agent) was the most suitable, both on account of the retention of carbon dioxide and the danger of incomplete dissociation of the carbonates in the combustion method. It is considered that, in general, the carbon analyses have an accuracy of $\pm 0{\cdot}05$ per cent., and the nitrogen $\pm 0{\cdot}003$ per cent.

In the Arabian Sea there is a large central area extending into the Gulf of Oman where the organic carbon content of the sediments is less than 1 per cent. Surrounding this is a belt containing 1 to 1·5 per cent., and then a coastal area with a greater organic carbon content. The distribution of organic matter is in general agreement with the productivity of the area determined from chemical studies and plankton hauls.

The C : N ratio in the surface samples varies between 4·9 and 34·2, though there is a tendency for a regional constancy of this ratio. The general average for the surface samples is 14·4. It has been suggested by some investigators that, as a routine procedure, the estimations of organic matter can be most satisfactorily obtained from nitrogen, but the authors consider that this is likely to lead to very inaccurate results because of the variability of the C : N ratio. In the lower portions of the cores organic carbon and nitrogen may decrease, increase, or oscillate. These variations of the C : N ratio in the lower portions agree, in general, with the variations of the $CaCO_3$ content, and a possible explanation for this is suggested.

Finally, it is pointed out that the organic content of marine sediments is of special importance to those who are interested in the nitrogen cycle and the regeneration of organic matter, and to the ecologist the question as to whether this organic matter is inert or is available as a nutrient for bottom fauna is a problem of special interest. In addition, the oil geologist is interested in the potentiality of sediments as source beds, and it would seem likely that the more organic matter such a sediment contains, the more likely it is to be a source bed. It is to be hoped that future expeditions studying the productivity of the oceans will not ignore the information which may be obtained from the sediments, and will collect bottom samples with all possible oceanographical data. By this more useful results will undoubtedly be obtained which will be helpful in the interpretation of other problems.

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